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The Ordovician Fossils from the McKay Group in
British Columbia, Western Canada, with a Note
on the Early Ordovician Palaeogeography

By

Teiichi KOBAYASHI

Preface

All of the fossils described in this paper belong to EVANS' collection from the McKay group in the Columbia river valley in British Columbia with the exception of one which was procured from Mount Norquary by WARREN. The collection comprises a cephalopod, several species of gastropods and some 50 species of trilobites, besides undescribed graptolites and brachiopods. It is hoped that their description will be an addition to the knowledge on the Ordovician fauna in western Canada.

While a great variety of trilobites can be recognized in the collection, none of them is represented by a complete carapace. Because of the state of preservation the present material is not comparable with silicified ones, and little can be added to ventral morphology or ontogeny of trilobites. There are, however, several genera and many species new to palaeontology.

I have tried to analyze the faunas from various points of view to ascertain their chronological relation, because little is known of the stratigraphic succession of the fossil beds. In describing Upper Cambrian fossils of the same area, I have paid special attention to *Glyptagnostus* and *Parabolinella* (1938). It is interesting to me to find again some trilobites which reveal Atlantic affinity of the Ordovician fauna, although many others are typical members of the Arcto-American fauna. On this occasion a lengthy discussion is presented on the bearing of the faunas on the Ordovician palaeogeography.

I wish here to record my cordial thanks to Dr. C.S. EVANS, Prof. P.S. WARREN, the late Dr. E. M. KINDLE, Dr. Hans FREBOLD and the late Dr. C. E. RESSER for the privilege of studying these interest-

ing fossils and for information as to their localities. My thanks are also tendered to Messrs. T. ICHIKAWA, C. UEKI and S. SUZUKI for cleaning, photographing or drawing of the fossils and to Dr. S. KOBE for editing. Finally I wish to thank Mrs. KOBAYASHI for the assistance she has given in typewriting this manuscript. All of the specimens described in this paper are kept in the Geological Survey of Canada at Ottawa.

April 30th, 1955

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Chapter I.

Stratigraphy of the McKay group and EVANS' Collection of its Fossils

According to EVANS (1933) the McKay group lies on the Jubilee limestone (Middle and/or Upper Cambrian) in the southeastern part of the Brisco-Dogtooth Map-Area and on the Canyon Creek slates (Middle? Cambrian) in its northwestern part. Because of its typical display the name of the formation was taken by him from John McKay Creek, a tributary of Sinclair Creek which is in turn a branch of the Columbia river.

The McKay group is a thick formation over 4000 feet in total thickness, which consists mostly of thin and thick bands of blue-gray limestone and gray shale in alternation and includes many fossiliferous beds from Upper Cambrian to Chazyan. The basal part is, however, quite shaly and contains 6 to 12 inch beds of light blue crystalline limestone. The lower part is massive blue limestone; the middle part composed of alternations of shales and limestones in which intraformational limestone conglomerates are frequently intercalated; the upper part is thin bedded and rusty from weathering, with ripple marks and mud cracks.

In the Brisco and Van Horne ranges the upper alternating portion of the group to some thickness is heteropic to the Glenogle shales which are composed of arenaceous shales, black shales and limy shales in addition to several massive quartzite beds, 8 to 10 feet thick in 100 feet near the top. The Glenogle graptolites are intimately related to the Deep Kill and Normanskill faunas. The McKay group in addition to the Glenogle shales is overlain by the Wonah quartzite. Above this quartzite the Richmondian Beaverfoot formation and the Gotlandian Brisco formation were accumulated one after another.

Table 1. Relation of the McKay Group to the Glenogle
and other formations.

WALCOTT		EVANS	
Chazyan and Canadian	Glenogle	Chazyan and Beekmantown	Glenogle
Canadian	Sarbach	Beekmantown	
Ozarkian	Mons	to	McKay group
Upper Cambrian	Sabine ?	Upper Cambrian	

The McKay group comprises the Glenogle, Sarbach, Mons and possibly Sabine formation in WALCOTT's classification as shown in the table 1. For any further information on the stratigraphy the reader is referred to EVANS' report (1933).

The fossils dealt with in this paper were collected from the localities listed below.

List of Fossil Locality

All from Columbia River Valley, British Columbia
 Informations given by E. M. KINDLE and C. E. RESSER.

1. 7899. Rocky Mountain Quartzite, Mount Norquay. (P. S. WARREN, 1923)
2. 7977. Goodsir No. 37/7.
 North of forest stream from East, North of Brisco trail, elevation 5250'. (North Rock Vermilion, 1 mile north of Banff, Brisco trail).
3. 7978. 33/4
 2' above 33/3, No. 8120, Vermilion basin. Headwaters of Pinnacle creek, Brisco range, Elevation ca 7500', 4.5 miles northeast of Brisco station.
4. 7999. Goodsir, No. 8/11
 On Harrogate section, 117'-350' below 1st quartzite.
5. 8005. Goodsir, No. J/8
 At head of Creek, 3.1 miles North of Sinclair, elevation 7450'.
6. 8032. Goodsir, No. 7.
 No locality given.
7. 8064. Goodsir, No. 14/3
 South of Whiskey trail, elevation 7000'.
8. 8106. No. 35/1
 On spur northeast of Brisco trail crossing at elevation 5750'. (Big Vermilion).
9. 8117. Glenogle, No. 33/1.
 North Vermilion basin, elevation 8100'.
10. 8118. Glenogle, No. 33/2.
 Vermilion basin, elevation 8050'.
 (10a and 10b are distinguished from 10 by lithology).
11. 8120. Goodsir, No. 33/3.
 North Vermilion basin, elevation 7700'.
12. 8128. Goodsir, No. 37/3
 North of 1st stream from East, North of Brisco trail, elevation 5500'. (1 mile North Banff, Brisco trail, North Folk, Vermilion).
13. 8139. Goodsir, No. 52, below quartzite.
 McKay Creek section, below quartzite 115'.
14. 8146. McKay Creek.
15. 8160. Goodsir, No. 52.
 McKay Creek section below quartzite 2939'.
16. 8161. Goodsir, 52 (52/3035, McKay Creek)
 Section 52 below quartzite 3035'.

17. 8164. Goodsir, No. 53.
1 mile south of No. 52, west side of McKay Creek. 1.5 miles from Sinclair.
18. 8171. Goodsir, No. 57.
North end, Steamboat Mountain, east slope, elevation 3700'.
19. 8173. Goodsir, No. 57/4.
North end, Steamboat Mountain, east slope, elevation 4250'.
20. 8211. Goodsir, No. 22
Elevation 6000' just south of third creek, southeast of Harrogate.
21. 52/139. McKay Creek.
22. 53/5. Section of McKay group, 1 mile north of Sinclair Creek on west side of McKay Creek.
23. 54/1. 2 miles south of Sinclair Creek, 3 miles northeast of Columbia river, Elevation about 5600'.
24. 58/1. $\frac{3}{4}$ miles east of Grant Mine, Jubilee Mountain, Elevation ca 5200'. South of Harrogate, west side of Columbia River.
25. V/4. Have no number V/4 or no record of it. (1 mile North Harrogate, on label).
26. 7/b. 7985. North of 1st stream from East, North of Brisco trail.
27. C2. North of the 1st stream from East, North of Brisco trail.

The McKay group in the type section along John McKay creek where it underlies the Wonah quartzite is classified into the following 7 rock units in descending order. Cut by a fault, the base of the group is unexposed.

- VII. Gray crystalline limestone, 342 feet thick; a band of conglomeratic dolomite near the top.
- VI. Argillaceous limestone beds and shale layers and lenses, 116 feet thick; some layers replete with broken fragments of trilobites; a shallow concentration of shells and moults.
- V. Blue limestone, 373 feet thick; brachiopods in 5 horizons.
- IV. Unfossiliferous limestone with chert bands
- III. Unfossiliferous dolomitic limestone with chert bands
- II. Unfossiliferous crystalline limestone with chert bands
- I. Alternations of bluish gray or blue limestone and shales, 1565 feet thick; numerous limestone beds are intraformational conglomerates.

Putting aside the three unfossiliferous units (II, III, and IV), trilobites and graptolites are reported from 9 horizons in 3 other units (I, VI and VII). The collection at hand contains fossils from 6 localities in John McKay creek. Three of them (locs. 13, 15 and 16) can be exactly allocated in the type section, but not the other three. From the occurrence of asaphids (*Kobayashia*), however, it is presumed that loc. 14 belongs to either one of the three horizons, 4, 5, and 6. Because *Kirkella* or *Protopliomerops* is procured respectively from loc. 17 or loc. 21, these two localities are thought to be near loc. 13. Neither *Kainella* nor the like is contained in the McKay

creek collections at hand. The relation of these fossil localities to the fossil horizons in EVANS' report is shown in the table given below.

Table 2. Fossil horizons in the McKay Creek type section.

	A	B	C	D	E
9.	57	VII	<i>Phyllograptus</i>	<i>Ampyx</i> zone	Locs. 13, 17, 21.
8.	115	VII	<i>Isoteloides</i>	<i>Megalaspis</i> zone	
7.	139	VII	<i>Amphion-Diplograptus</i>	<i>Diplograptus</i> zone	
6.	319	VI	<i>Xenostegium</i>	<i>Xenostegium</i> zone	Loc. 14.
5.	477	VI	<i>Isoteloides</i>		
4.	489	VI	<i>Megalaspis</i>		
				<i>Ozarkispira</i> zone	
3.	2161	I	<i>Kainella</i>	<i>Kainella</i> zone	
2.	2939	I	<i>Symphysurina</i>	<i>Symphysurina</i> zone	Loc. 15.
1.	3035	I.	<i>Symphysurina</i>		Loc. 16.

A. Numerals in feet below the Wonah quartzite.

B. Rock units in Roman numerals.

C. Leading genera (RUEDEMANN's and RESSER's determination).

D. Fossil zones in EVANS' report.

E. Fossil localities in this paper.

The *Symphysurina* limestone is widely distributed on the east and west sides of the Columbia river. At the north end of the eastern slope of Steamboat mountain it is found at elevations of 3700 feet and 4250 feet (locs. 18 and 19). The collections from loc. 24 on Jubilee mountain and loc. 19 of Steamboat mountain are especially rich in genera and species. In the McKay creek section the limestone at loc. 15 lies 96 feet above that at loc. 16, this fact showing that the *Symphysurina* fauna occurs in two or more horizons. It is known to occur also at locs. 22 and 23 in the Sinclair canyon and locs. 10a and 10b in the Vermilion basin.

The *Kainella-Evansaspis* fauna was procured from locs. 2, 8, 12, and 27 on the Brisco trail and from loc. 25 in the north of Harrogate. The collection from loc. 2 contains a copious fauna composed of some 15 species. The *Lingukainella* faunule from loc. 7 on Whiskey trail may be nearly coeval with the preceding as *Paenebeltella convexa* and *Gonioteloides* are found to be common to both the two localities.

It is probable that the gastropod limestones at locs. 5 and 6 are also approximate in age to the preceding because *Ozarkispira* is

common to locs. 6 and 7 and *Raphistomima sinclairiensis* to locs. 2 and 5.

Table 3. *Symphysurina* Fauna

	Loc.									
Specific name	10a	10b	15	16	18	19	22	23	24	
<i>Eobucania pulchra</i>					x	x				
<i>Symphysurina</i> (<i>Symphysurina</i>) <i>spicata</i>					x					
<i>S.</i> (<i>Symphysurina</i>) <i>spicata eugenia</i>									x	
<i>S.</i> (<i>Symphysurina</i>) cfr. <i>corlissensis</i>									x	
<i>S.</i> (<i>Symphysuroides</i>) <i>elegans</i>							x			
<i>S.</i> (<i>Symphysuroides</i>) <i>expansa</i>									x	
<i>S.</i> (<i>Symphysuroides</i>) cfr. <i>brevispicata</i>		x		x			x	x		
<i>Symphysurina</i> a sp.						x				
<i>Symphysurina</i> b sp.			x			x		x		
<i>Bellefontia platana</i>			x							
<i>Columbicephalus macrops</i>	x									
Asaphid, spp. indt. (b, c)									x	
<i>Goniateloides monoceros</i>										
<i>Eulomella mckayensis</i>					x					
<i>Neotaenicephalus obsoletus</i>									x	
<i>Hystericurus</i> cfr. <i>genalatus</i>									x	
<i>Hystericurus</i> sp.							x			
<i>Hystericurus</i> (?) sp.								x		
<i>Amechilus tuberculatus</i>									x	
<i>Macroculites enigmaticus</i>									x	
<i>Parabolinella bisulcatus</i>										
<i>Sphaerophthalmella inexpectans</i>						x				
<i>Jujuyaspis borealis</i>						x				
<i>Lunacrania trisecta</i>									x	
<i>Rhamphopyge altipolum</i>									x	
Gen. and spp. indt. (free cheeks)							x			
<i>Neoagnostus aspidoides</i>									x	
<i>Geragnostus</i> aff. <i>mundus</i>								x		
<i>Trinodus priscus</i>			x							

Apatokephalus canadensis was obtained at loc. 26 on the Brisco trail and at loc. 20 in the southeast of Harrogate. At the latter it is accompanied by a few asaphids and *Peltura pacifica* which occurs together with an indeterminable Nileidae at loc. 9 in the North Vermilion basin. There is thus some relation among the fossils from

the three localities. Therefore they are tentatively assembled into the *Peltura-Apatokephalus* faunule. This faunule has no species or genus in common with the *Kainella-Evansaspis* fauna, but it is related to the asaphid faunule from locs. 1, 3, 4, 11 and 14.

These asaphids are presumed to have been obtained from different horizons. In the Pinnacle trail, loc. 3 is said to be located 2 feet above loc. 11.

Robsonoceras (?) sp. from loc. 3 is the solitary nautiloid in the collection at hand. Likewise, *Ellesmereoceras* (?) is the only nautiloid of the McKay group in EVANS report. Therefore it is highly probable

Table 4. The *Kainella-Evansaspis* fauna and its allies

Specific name	Loc.							
	2	5	6	7	8	12	25	27
<i>Raphistomina sinclairensis</i>		x						
<i>R. sinclairensis acuta</i>	x							
<i>Lytospira mediosulcata</i>			x					
<i>Ozarkispira leo</i>			x					
<i>Ozarkispira</i> sp. indt.				x				
<i>Kainella kindeli</i>	x							
<i>Kainella stenorachis</i>								x
<i>Lingukainella robusta</i>				x				
<i>Tesselacuada flabella</i>	x							
<i>Leiostegium (Evansaspis) glabrum</i>	x				x	x	x	
<i>Hyperbolochilus expansus</i>	x							
<i>Symphysurina</i> b sp.	x							
<i>Gonioteloides monoceros</i>	x							
<i>Gonioteloides punctatus</i>				x				
<i>Vermilionites bisulcatus</i>					x			
<i>Hystericurus platypleurus</i>	x							
<i>Parahystericurus</i> (?) sp.	x							
<i>Clelandia</i> (?) sp.	x							
<i>Dimeropygiella eos</i>				x				
<i>Metabowmania latilimbata</i>	x							
<i>Amechilus tuberculatus</i>	x							
<i>Paenebeltella convexa</i>	x			x				
<i>Ampyx</i> sp.				x				
<i>Shumardia</i> sp.	x							
Gen. et sp. indt. (free cheek)	x							
<i>Hyperagnostus binodosus</i>	x							

that this *Robsonoceras* (?) sp. is nothing but *Ellesmereoceras* sp. which RESSER identified for EVANS.

In ULRICH and others' monograph on the Ozarkian and Canadian cephalopods (1944) *Ellesmereoceras robsonensis* WALCOTT from the Mons in Alberta is referred to *Robsonoceras* and this genus is noted to be common in the *Leiostegium* zone of the Chushina formation in British Columbia, but no species of *Ellesmereoceras* is described in the monograph from western Canada.

Beside the nautiloid *Plectorthis*, *Xenostegium*, *Bellefontia* (?) and *Isoteloides* are noted by RESSER as members of the *Ozarkispira* zone. The asaphids associated with *Robsonoceras* (?) at loc. 3 could be those which RESSER called *Xenostegium*, *Bellefontia* (?) or *Isoteloides*. I cannot, however, convince myself of their reference to the *Ozarkispira* zone, because, as listed in the preceding page, *Ozarkispira* from locs. 6 and 7 as well as *Raphistomina* from locs. 2 and 5 are all isolated from these fossils from loc. 3 or any other of the asaphid fauna.

In the type section of John McKay creek the II, III and IV divisions of the group are unfossiliferous and the *Ozarkispira* zone is unrepresented. The asapid faunule from loc. 14 which contains *Kobayashia* must have been obtained from either one of the *Xenostegium* (6), *Isoteloides* (5), or *Megalaspis* (4) horizon, because it is quite different from the *Protopliomerops-Kirkella* faunule at loc. 13 in the so-called *Isoteloides* (8) horizon.

Table 5. The *Apatokephalus-Peltura* faunule (locs. 9, 20, 26) and the asaphid faunules (locs. 1, 3, 4, 11 and 14).

	Loc.							
Specific names	1	3	4	9	11	14	20	26
<i>Robsonoceras</i> sp.		×						
<i>Apatokephalus canadensis</i>							×	×
Nileidae (?) gen. and sp. indt.				×				
<i>Bellefontia</i> (?) aff. <i>collicana</i>			×					
<i>Bellefontia</i> (?) sp.			×					
<i>Asaphellus</i> (?) <i>canadensis</i>							×	
<i>Kobayashia lanceolata</i>			×			×		
<i>Kayseraspis</i> (?) <i>eulides</i>		×	×		×		×	
<i>Kayseraspis</i> (?) sp.	×				×			
<i>Protopresbynileus</i> (?) aff. <i>willdeni</i>			×			×		
<i>Peltura pacifica</i>				×				
<i>Peltura canadensis</i>							×	

The asaphoid pygidium with a posterior pit on the doublure or *Protopresbynileus* (?) aff. *willdeni* is known to occur at locs. 4 and 14. The former locality is said to lie in the Harrogate section 117 to 350 feet below the first quartzite of Wonah and the trilobites are contained in light gray crystalline limestone.

Insofar as the present collection is concerned, the asaphid faunule appears to be widely ranged. It is related to the *Apatokephalus* faunule, but there is none which is common with the *Evansaspis* fauna or the *Ozarkispira* faunule.

Table 6. The *Kirkella-Protopliomerops* Fauna (Locs. 13, 17, 21) and the *Telephus* Faunule (Loc. 10).

Specific name	Loc.	10	13	17	21
<i>Burnesella tympana</i>				×	
<i>Protopliomerops subquadratus</i>					×
<i>Protopliomerops radiatus</i>			×		
<i>Protopliomerops longispinus</i>			×		
<i>Telephus pacificus</i>	×				
<i>Kayseraspis</i> (?) <i>euclides</i>				×	
<i>Kirkella</i> cfr. <i>vigilans</i>			×	×	
Asaphid, gen. et sp. indt. (pygidium).			×		
<i>Licnocephala longa</i>			×		
<i>Lachnostoma</i> (?) sp.			×		
<i>Ampyx walcotti</i>			×		
<i>Ampyx</i> sp.		×			
<i>Trinodus tardiformis</i>		×			

Finally there are two faunal assemblages. One is the *Kirkella-Protopliomerops* fauna from locs. 13, 17 and 21 in the McKay creek. The most important of these three localities is loc. 13 which yields 6 species, i.e. the so-called *Isoteloides* (8) horizon in the type section located 115 feet below the Wonah quartzite. The fossil horizons at locs. 17 and 21 are, judging from the contents, not much different from those at horizon 8. The other of the two assemblages is represented by the *Telephus-Ampyx* faunule. Loc. 10 in the Vermilion basin yields a distinct faunule in which *Ampyx* is the most common trilobite.

In summarizing these facts the following 7 faunal assemblages can be distinguished in the collection at hand.

- The *Telephus-Ampyx* faunule (loc. 10.)
- The *Kirkella-Protopliomerops* fauna (locs. 13, 17, 21)
- The Asaphid faunule (locs. 1, 3, 4, 11, 14.)
- The *Apatokephalus-Peltura* faunule (locs. 9, 20, 26.)
- The *Ozarkispira-Raphistomina* faunule (locs. 5, 6.)
- The *Kainella-Evansaspis* fauna (locs. 2, 7, 8, 12, 25, 27.)
- The *Symphysurina* fauna. (locs. 10a-b, 15, 16, 18, 19, 22, 23, 24.)

Chapter II.

The Ages of the Ordovician Faunas in the McKay Group

Through EVANS' field observations combined with preliminary determinations of graptolites and other fossils by RUEDEMANN and RESSER, 8 fossil zones were distinguished in the McKay group as follows:—

- | | |
|-----------------------------|--------------------------------|
| 8. <i>Ampyx</i> zone | 4. <i>Ozarkispira</i> zone |
| 7. <i>Magalaspis</i> zone | 3. <i>Kainella</i> zone |
| 6. <i>Diplograptus</i> zone | 2. <i>Symphysurina</i> zone |
| 5. <i>Xenostegium</i> zone | 1. <i>Dicellosephalus</i> zone |

The fossils at hand which belong to a part of EVANS' collection were procured from numerous fossil localities in separate sections and their stratigraphic relation is not well known. Therefore I have tried to group the fossils into faunas or faunules with reference to their association at each locality. As the result 7 faunal assemblages were obtained. It is the principal object of this chapter to check on the time relation among these faunas with reference to the existing knowledge on the Ordovician zonation in the Cordilleran region.

WALCOTT (1924) has distinguished in the Mons formation the four zones which were called *Briscoia*, *Symphysurina*, *Hungaia* and *Ozarkispira leo* zones. Incidentally this *Hungaia* zone must be the *Kainella* zone, because *Hungaia billingsi* WALCOTT which was the zone index was later chosen for the type species of *Kainella* by WALCOTT. He placed the Mons in the Ozarkian, but stated that "the lower Mons (*Briscoia*) faunule is strongly related to that of the Upper Cambrian and the upper faunule has a large proportion of genera of an Ordovician facies." In agreement with WALCOTT, I do not hesitate to draw the Cambro-Ordovician boundary between the *Briscoia* and *Symphysurina* zones.

In my previous paper (1938) the *Plethopeltis*-bearing gray limestone of Mount Jubilee was referred to the first or *Briscoia* zone, because it yields *Briscoia* (?) *latimarginalis* KOBAYASHI.

In the Sinclair canyon section which WALCOTT (1924) took for the standard in the Brisco-Stanford range, the lower division (4) of the Mons formation comprises 4 fossiliferous horizons. *Briscoia* is a common genus in the middle two. The upper one of this division

which yields *Taenicephalus* is also Upper Cambrian.

In the middle part (2 and 3) of the Mons the lower beds contain *Symphysurina*, but not *Hungaia* (i.e. *Kainella*) and the two genera occur together in the upper beds. *Ozarkispira leo* is known from the upper division (1).

The Soddary-Dry creek section is also provided with the aforementioned four zones. There *Hungaia* (i.e. *Kainella*) is not accompanied by *Symphysurina*.

In WALCOTT's later paper (1928) the manuscript of which was altered by RESSER before its publication, it is cited that *Kainella* and *Leiostegium* occur in the Fossil Mountain section in the horizon lower than *Symphysurina* (?) in the lower part (1b) of the Mons formation. These three genera of trilobites are, however, found together at Billings Butte in a horizon of the Chushina formation in Robson Peak area.

The coexistence of the three genera is found at loc. 2 in the Columbia river valley, but such an occurrence is unusual in the McKay group. The above mentioned superposition of the *Symphysurina* zone on the *Kainella-Leiostegium* zone is just the reverse to the exact zonation of the Lower Ordovician formation in Utah and Nevada which was lately elaborated by ROSS (1951) and HINTZE (1952).

According to ROSS (1951) *Symphysurina* occurs in his A and C zones whereas *Leiostegium manitouensis* appears in his D zone of the Garden City formation. According to HINTZE (1952) *Symphysurina* is restricted to his B zone i.e. *Symphysurina* zone and *Leiostegium (Evansaspis) formosa* occurs in the *Tesselacauda* or E zone which lies above the *Leiostegium manitouensis-Kainella* zone or D zone of the Pogonip group.

As mentioned before, *Symphysurina* and *Symphysuroides* are distributed widely in the Columbia river valley. The species of *Symphysurina* or *Symphysuroides* and their associates at the 9 localities of the *Symphysurina* limestone are, however, fairly different from one another. In fact there is no species common among 6 species from loc. 19, 3 species from loc. 22 and 8 species from loc. 24. Such a difference suggests that the *Symphysurina* fauna was derived from 3 or more horizons. Therefore the mutation of *Symphysurina* or *Symphysuroides* which took place during the deposition of these limestones is an interesting subject for future study. *Symphysurina* was declined but still survived until the *Evansaspis* hemera, as can

be recognized from the coexistence of the two genera at loc. 2.

The present collection contains no *Leioptegium*, s. str. *Leioptegium* (*Evansaspis*) *grabrum* which occurs at 4 localities must be a good guide fossil. It is found together with *Kainella stenorachis* at loc. 2.

It is noteworthy that the *Symphysurina* fauna and the *Evansaspis-Kainella* fauna still contain several trilobites of Cambrian aspects. They are *Hyperbolochilus*, *Neotaenicephalus*, *Vermilionites*, *Metabowmania*, *Amechilus* and *Sphaerophthalmella* to which *Parabolinella* may be added. These faunas are, however, quite different from the Croixian ones in the development of asaphids, hystricuroids, bathyurids (*Gonioteloides*), raphiophorids and cheiruroids (*Tesselacauda*). The inclusion of the true bucanid in the *Symphysurina* fauna is quite a remarkable fact.

These faunas must be early Ordovician in age. The inclusion of many Cambrian trilobite relicts in these faunas means that the faunal change from the late Cambrian to the early Ordovician period was relatively gradual in this part of the world. This is probably due to the fact that the change of the environment recorded in the lithofacies was so gradual that the *Briscoia* zone has to be combined with the three superjacent ones in a rock unit of the McKay group which was termed "Mons formation" by WALCOTT.

Paenebeltella convexa is a species and *Gonioteloides* a genus which are common to the faunules of locs. 2 and 7. *Ozarkispira* is another genus which occurs in common in those of locs. 6 and 7. From these facts it can be concluded that the *Ozarkispira* fauna and the *Evansaspis-Kainella* fauna are linked by the faunule of loc. 7.

Lingukainella and *Dimeropygiella eos* suggest that the faunule from loc. 7 is a little younger than that of loc. 2. *Lingukainella* is morphologically more developed than *Kainella*. Furthermore it is noteworthy that *Dimeropygiella* was founded by ROSS on *D. caudanodosa* from the J zone of the Garden City formation. Subsequently HINTZE described this species from the J zone of the Pogonip and *D. ovata* and *D. blanda* from the H zone of the same group. *D. eos* at hand looks older than these species, because it bears some aspect resembling *Hystricurus*.

Only gastropods were collected from locs. 5 and 6. *Raphistomina sinclairensis* is the solitary fossil from loc. 5, and its horizon may not be far apart from loc. 2 which yields *R. sinclairensis acuta*.

Ozarkispira leo which was procured from loc. 6 is the well known index to WALCOTT's zone of the same name.

Now WALCOTT's 4 fossil zones in the Mons are endorsed by these facts to be in the succession that he pointed out in 1929. From the above discussion the zonation can be made with greater accuracy, as suggested below.

1. There may be 3 or more subzones in the *Symphysurina* zone or limestone.

2. The *Kainella* zone may be splitted into the zone with *Leiostegium* s. str. and the other with *Evansaspis*.

3. The *Lingukainella* bearing horizon can be expected to be located between the *Ozarkispira leo* zone and the *Kainella-Evansaspis* zone.

Incidentally, the so-called Ozarkian fauna which KINDLE (1929) described from Jasper Park, Alberta, belongs, in my opinion, most probably to the *Symphysurina* fauna because his *Hardyia metion?* appears to be congeneric with *Lunacrania trisepta* and possibly so is *Symphysurina walcotti* KINDLE with *Bellefontia platana*.

In Utah and Nevada two series of fossil zones are designated by ROSS and HINTZE in alphabetical order. It is, however, noted by HINTZE that any two zones in the same letter designation contain fairly different faunas. Accordingly their synchronism may not be as accurate as they sound.

It is more difficult to correlate these zones with those in Canada. Nevertheless it is interesting to see that as in the Columbia river valley, *Symphysurina* occurs in 3 or more zones, namely in the B zone of the Pogonip group and in the A and C zones of the Garden City formation. There are two zones of *Leiostegium*, s. l. More precisely, *Leiostegium manitouensis* occurs both in the D zone of the Garden City and the D zone i.e. the *Leiostegium-Kainella* zone of the Pogonip group. *Evansaspis* is unrepresented in these zones, but represented by a species called *L. formosa* in the *Tesselacauda* or the E zone of the Fillmore limestone. In the Garden City formation *Tesselacauda depressa* occurs in the E zone.

Leiostegium manitouensis was described by WALCOTT (1925) from the Chushina formation of Mt. Extinguisher near Mt. Robson in British Columbia. The present collection does not contain this species, but the *Leiostegium* fauna may be nearly contemporaneous with the *Apatokephalus* bearing faunule from locs. 20 and 26 and the asaphid faunule of loc. 3 containing *Robsonoceras* (?), because it is

known that *Robsonoceras* is a common member in the *Leiostegium* zone and *Apatokephalus finalis* is reported from the *manitouensis* bearing D zone of the Pogonip.

The *Ozarkispira leo* zone is missing in the schemes of zonation achieved by ROSS and HINTZE, but *Raphistoma rotuliformis* MEEK which is, according to KNIGHT, (1941), probably identical with *Ozarkispira leo*, is presumed to have been procured somewhere near the F zone.

I cannot convince myself of the propriety of grouping the faunules from locs. 1, 3, 4, 11, 14 and 20 into the asaphid fauna, because as has been pointed out already, the faunules of locs. 3 and 20 are approximate contemporaries of the *Leiostegium* fauna. The faunule of loc. 4 which contains *Kobayashia* is probably younger and may be correlated to the G_1 to G_{2a} zones of the Garden City which yield "*Xenostegium*" *taurus*, *Asaphellus* (?) *eudocia* and *Macrapyge gladiator* (cephalon).

The *Kirkella-Protopliomerops* fauna or locs. 13, 17 and 21 appears to be still younger. According to HINTZE *Kirkella* is a long ranged genus from his G_2 to J zones, but *Kirkella* cfr. *vigilans* and *K. decliva* are limited to his J zone. In the Garden City formation the occurrence of the latter is also restituted to ROSS' J zone. Therefore the two species, *vigilans* and *decliva*, which are very similar to each other, may be important keys to correlation. *Protopliomerops* as a genus also ranges widely from the G_1 zone to the F zone in the Garden City formation and from the G_1 zone to the H zone in the Pogonip group.

Licnocephala longa and *Lachnostoma* (?) sp, are found at loc. 13. *Licnocephala* is known from the G_2 zone of the Garden City and from the F and G_2 zones of the Pogonip, while *Lachnostoma* is reported from the J zones of the two formations, In weighing these time ranges it may be said that the *Protopliomerops-Kirkella* beds in the McKay group are a little older than the J zones of the Pogonip as well as the Garden City formation.

A tentative correlation of the fossil beds in the McKay, Pogonip and Garden City formations is shown in the table given below.

In northeastern Utah the Garden City formation comprising the A to L zones is underlain by the Croixian St. Charles formation and overlain by the Swan Peak with the M zone. ROSS correlated the A and B zones to the Tribes Hill and Stonehenge in the eastern

Table 7. Correlation of the fossil beds in the McKay Group to the fossil zones in the Pogonip and Garden City formations.

McKay group	Pogonip group	Garden City formation
<i>Kirkella-Protopliomerops</i> beds	H-J zones	H-J zones
<i>Kobayashia</i> beds	G ₁₋₂ zones	G ₁₋₂ zones
<i>Ozarkispira</i> zone	F zone	F zone
<i>Evansaspis</i> beds	E zone	E zone
<i>Robsonoceras</i> (?)- <i>Apatokephalus</i> beds	D zone	D zone
<i>Symphysurina</i> beds	B-C zones	A-C zones

states and the C and D zones to the Manitou limestone in Colorado. Laying special stress on the occurrence of *Hesperonomia* and *Tritocoechia* in the J and K zones and of *Anomalorthis* in the L zone he drew the Canadio-Chazyan boundary between the K and L zones with the reservation that the boundary suggested by some trilobites may be a little lower.

In western Utah and eastern Nevada HINTZE found two more zones in the Pogonip group which are higher than the M zone of the Swan Peak, but considered to be still in the Chazyan. As for the Chazyo-Canadian boundary he drew it between his K and L zones.

The faunule of loc. 10 must be the youngest of the McKay faunas because *Telephus* is unknown from pre-Chazyan formations. In North America *Telephus* is most common in the Blount formation in the southern Appalachians.

The relation of the faunal assemblages to EVANS' fossil zones is

Table 8. Relation between the faunas classified here and the fossil zones cited in EVANS' report, 1933.

KOBAYASHI (1955)	EVANS (1933)
<i>Telephus</i> faunule	<i>Ampyx</i> zone
<i>Kirkella-Protopliomerops</i> fauna	<i>Megalaspis</i> zone
	<i>Diplograptus</i> zone
<i>Kobayashia</i> faunule	<i>Xenostegium</i> zone
<i>Ozarkispira</i> faunule	<i>Ozarkispira leo</i> zone
<i>Lingukainella</i> faunule	
<i>Evansaspis-Kainella</i> fauna	} <i>Kainella</i> zone
<i>Robsonoceras</i> (?)- <i>Apatokephalus</i> faunules	
<i>Symphysurina</i> fauna	<i>Symphysurina</i> zone

suggested in the table 8.

Now we shall examine the distribution of more important genera in North America. *Symphysurina*, inclusive of *Symphysuroides*, is the most important genus marking off the base of the Ordovician system. In the Yukon-Alaska boundary region *Symphysurina tatondukensis* (nov.) occurs at Jones ridge, north of the Tatonduk river and *S. spicata* on the Squaw mountains (KOBAYASHI, 1936). The genus is represented by a great variety of species in Alberta and British Columbia as well as in Utah and Nevada.

S. spicata is known to occur in the *Bellefontia* zone at the top of the Pilgrim formation in central Montana (LOCHMAN and DUNCAN, 1950). This species beside two others of the genus is listed from the Simpson Spring Mountain boulders (KING, 1937) and *S. cfr. woosteri* from the Wood Hollow boulders, all in the Marathon uplift in western Texas (WILSON, 1954). Furthermore *Symphysurina* is found together with *Hystericurus* in the McMichel member of the McKenzie Hill formation of Oklahoma (FREDERICKSON, 1941).

S. woosteri is the type species of the genus which was primarily described from the Oneota dolomite in Wisconsin. While the axial lobe of the pygidium is usually protruded into a caudal spine in ULRICH's types, the spine is undeveloped in the pygidia from the same limestone in Minnesota which POWELL (1935) referred to the species. STAUFFER and THIEL (1941) added later *S. spicata* to the Oneota fauna of Wisconsin.

Symphysurina is represented in the Mohawk valley and New Jersey by a few species described by CLELAND (1900, 03) and WELLER (1902). In Vermont some others are described by RAYMOND (1937) and SHAW (1951) from the Corliss conglomerate or the uppermost Gorge formation.

Asaphus illaenoides BILLINGS from Limestone, No. 3, in the conglomerate of Lévis, Quebec is the oldest of *Symphysurina* among the dates of specific descriptions. According to RASETTI (1943) *Symphysurina* is contained with *Leioptegium*, *Kainella*, *Diplapatokephalus* and others in a same boulder at Lévis.

Kainella was founded by WALCOTT (1925) on *Hungaria billingsi* WALCOTT from the Chushina formation in eastern British Columbia and *Dicellosephalus* (?) *flagricauda* WHITE, 1874, and *Dicellosephalus inexpectans* WALCOTT, 1884, both from Nevada, were referred to it. Of its generic distribution he mentioned "Cordilleran area of Canada

and the United States, Province of Quebec at Point Lévis and possibly Vermont in Champlain Valley." Lately RASETTI (1943) described *Kainella orientalis* from the Lévis conglomerate.

Apatokephalus is a cosmopolitan genus, but so far as I am aware, *A. canadensis* in the McKay group is a solitary member of *Apatokephalus*, s. str. in North America. Its subgenus, *Diplapatokephalus* is on the other hand indigenous to the continent where it is represented by the following species:—

Dicellosephalus finalis WALCOTT, 1884, from the lower Pogonip of Nevada.

Diplapatokephalus multispinosus RAYMOND, 1937, from the lower Highgate of Vermont.

Diplapatokephalus levisensis RASETTI, 1943, from the Lévis conglomerate of Quebec.

Finalis was primarily described by WALCOTT as a companion trilobite of *Symphysurina eurekaensis* in the Eureka district, but the species is listed also as a member of the *Leiostegium-Kainella* (D) zone (HINTZE, 1952).

As summarized by HINTZE, there are eight species of *Leiostegium* which are widely distributed in North America as follows:—

Bathyrurus quadratus BILLINGS, 1860, from the Lévis conglomerate in Quebec.

Bathyrurus maccoyi WALCOTT, 1884, from the Pogonip of Nevada.

Leiostegium puteatum RAYMOND, 1924, *L. cingulosum* RAYMOND, 1924, *L. oblectum* RAYMOND, 1937 and *L. elongatum* RAYMOND, 1937 from the Highgate in Vermont.

Leiostegium manitouensis WALCOTT, 1925, from the Manitou limestone in Colorado, the Chushina formation in British Columbia and the D zones of the Garden City and the Pogonip in Utah and Nevada.

Its subgenus, *Evansaspis*, is however, so far represented only by the following three Cordilleran species:—

(?) *Crepicephalus ceratopygoides* RAYMOND, 1925, from the Lower Ordovician in British Columbia.

Leiostegium formosa HINTZE, 1952, from the E zone of the Pogonip of Nevada and Utah.

Leiostegium (*Evansaspis*) *glabrum* KOBAYASHI, from the McKay group in British Columbia.

Robsonoceras is a characteristic member of the *Leiostegium* fauna in the Cordilleran province. One is *R. robsonense* (WALCOTT), 1924, which is said to be abundant in the *Leiostegium* zone of the Chushina formation in British Columbia and occurs also in the Mons formation in Alberta. The other is *R. manitouensis* ULRICH, FOERSTE, MILLER and UNKELSBAY, 1944, from the *Leiostegium* zone of the Manitou limestone in Colorado.

The above mentioned genera are all characteristic members of the early Canadian fauna. *Symphysurina* and probably *Diplapato-*

kephalus flourished in the early part of the lower Canadian, but declined in the latter part when *Kainella*, *Leiostegium* and *Robsonoceras* developed.

According to BRIDGE and CLOUD (1947), *Burnesella* is distributed in "Lower Ordovician strata of post-Roubidoux age in Newfoundland, the Champlain Valley of Vermont, the southern Appalachian region, Oklahoma, Texas and Colorado."

KIRK (1934) once noted that *Asaphus* (?) *curiosus* would be a leading fossil in the Upper Canadian *Taffia* zone. It is the type species of *Kirkella* which was collected from the Mystic conglomerate at Stanbridge. As pointed out by HINTZE, its associates at this locality bear a Chazyan aspect, but it is questionable whether they were in the same boulder with *Kirkella curiosa*.

The genus is better represented in the west than in the east. Its vertical range as determined in the Pogonip by HINTZE is much wider than was previously thought, but is still pre-Chazyan.

Likewise, the life range of *Protopliomerops* as a genus is fairly long. It is apparently unrepresented in the faunas in the central and eastern parts of the continent. Combined with *Burnesella*, *Kirkella* and *Protopliomerops* would be important keys to the Upper Canadian strata.

The known distribution of *Ozarkispira* is restricted to the Cordilleran province. In western Canada the *Ozarkispira* zone appears to lie at about the middle of the Canadian sequence. In glancing over the Canadian fauna of the McKay group, a remarkable difference between the trilobite assemblages older and younger than the *Ozarkispira* zone can hardly be overlooked. Namely, the older ones contain, like the Tremadocian fauna, Cambrian relicts in not a small number. Like the Arenigian fauna, the younger ones are composed principally of the post-Cambrian members.

Chapter III.

The Bearing of the McKay Faunas on the Palaeogeography

As a sequence to the preceding chapter, the relationship of the fauna in the Cordilleran geosyncline where the McKay group is a member of its sediments, to those of the Arctic, Atlantic, Anden, Asiatic and Australasian provinces is discussed here. The principal part of the McKay fauna is occupied by trilobites. Therefore the discussion is extended to the problems on the rise and fall of certain genera and families of the trilobites as well as their migration or dispersal which took place through the geosynclines.

It was in 1933 that I discussed the Ozarkian problem at a session of the XVI International Geologic Congress at Washington, D.C. It is now solved, but when we ask again why it was that it raised such a moot question, the essential nature of the Croixian and Canadian series and the contained faunas and their special bearing on the Cambro-Ordovician history will be readily understood. In 1937 I presented a paper to the XVII International Geologic Congress at Moscow in which the palaeogeography of the late Cambrian and early Ordovician epochs was figured out. In adding new facts gathered since then, the epirogeny which caused geographic changes is brought into discussion to determine whether it is ubiquitous or non-ubiquitous. It is a fundamental problem in geology, and it is still far from a final solution. It is hoped such an attempt will be made as a step.

A. The Relation of the McKay Faunas to the Arctic ones

The Cambro-Ordovician faunas in Greenland and its adjacency were brought to light by HOLTEDAHL, POULSEN, TROEDSSON, FOERSTE and others. The Pemmican River formation containing *Elrathiella* and the Cape Frederik VII containing *Clavaspidella*, *Prosymphysurus* and *Ptychoparella* were thought to be lower Ozarkian, when the Ozarkian problem was unsolved, but are now considered to be Middle Cambrian. No Upper Cambrian fossil has yet been found in the region (POULSEN, 1946).

From the Bache peninsula HOLTEDAHL (1913) has reported *Illae-nurus* sp. and *Ptychoparia* sp., but *Symphysurina* and *Hystriurus*

were later suggested for the respective species (KOBAYASHI, 1934). As this suggestion was endorsed by POULSEN (1946), they are indeed, Lower Ordovician tribolites, instead of Cambrian ones.

NALVIKIN'S proposal on the Upper Cambrian emergence of the Arctic province (1937) is thus tenable for the side of Greenland, but not on the other side of the north pole.

The *Koldinia* fauna in Novaya Zemlya was formerly regarded as being Ozarkian or lower Ozarkian by WALCOTT (1924), WALCOTT and RESSER (1925) and LERMANTOVA and LAVROVA (1932), but is undoubtedly Upper Cambrian, as was pointed out before by the author (KOBAYASHI, 1935, 37, etc.) It was correlated to the *Agnostus pisi-formis* zone of the Olenidian and the Iroton of the Croxian by HOWELL and LOCHMAN (1939). It was known to reveal an early Upper Cambrian province when its wide distribution was found in Central Siberia from the Chatanga-Anabar basin to the Kuznetsk basin (LERMANTOVA, 1940, KOBAYASHI, 1943).

Plethopeltis, *Esseigania* and a few others suggest the flooding of the late Upper Cambrian sea on Central Siberia. The *Briscoia* fauna in Alaska (KOBAYASHI, 1935) is the definite proof for the connection between the Fengshanian sea in Eastern Asia and the late Croixian one in North America.

I do not know of any fossil from Central Siberia which indicates the presence of the Lower Ordovician rocks definitely. Along the Atlantic side of the Caledonian geosyncline, however, Canadian fossils occur in North Scotland, Smøla island of Norway and Bear Island. In the Durness limestone in Scotland *Paradoxides* and Canadian fossils were discovered respectively in lower and higher beds. There is a palaeontological hiatus at Upper Cambrian, although no stratigraphic break is proven.

These existing facts bear potential value on the hypothesis on epirogeny in alternate steps between the two sides of the Arctic province. In Greenland where no Upper Cambrian rock is known, there is a good display of the Lower Ordovician strata.

The Cass Fjord and Cape Clay formations have first been taken for upper Ozarkian by POULSEN (1924). But as has been pointed out elsewhere (KOBAYASHI 1934), the systematic boundary must be drawn through the so-called Ozarkian system. Furthermore I suggested that the *Symphysurina* fauna in the Arctic must be basal Ordovician (1937). This suggestion was vindicated by POULSEN (1937) with dis-

covery of *Clonograptus tenellus* (LINNARSSON) var. *callavei* LAPWORTH in the Cass Fjord formation. He mentioned that "the Cass Fjord formation is a stratigraphic equivalent of the upper portion of the Scandinavian *Dictyonema* shale and the *Clonograptus* zone of the British Shineton shale (Tremadocian)."

Symphysurina and hystriuroids are leading members of the Cass Fjord and Cape Clay faunas. POULSEN (1946) traced their distribution from Greenland into Ellesmere land and the Bache peninsula. In further beyond there are *Symphysurina* faunules in the Yukon-Alaska boundary region. On the Squaw mountains there are two *Symphysurina* limestones. The lower one includes some brachiopods similar to those in the *Briscoia* faunas of Alaska whereas the upper one, like the Cass Fjord fauna, does not contain such elements of Upper Cambrian aspect. In the faunal aspect the lower one may be compared in some way to the *Symphysurina* faunule of loc. 19 and also the *Evansaspis-Kainella* faunule of loc. 2 which include the Olenidae or other Cambrian relicts.

It was the general tendency in the Arctic province that the submerged area was shifted from Northern Eurasia in the early Upper Cambrian to Alaska in the late Upper Cambrian epoch. It is supposed that the sea was lingering in the northern Cordilleran geosyncline where the Cambrian relicts survived.

Upon entering into the Canadian epoch, however, the sea flooded along the Franklin geosyncline and extended beyond the Kane basin. *Symphysurina* developed as well there as represented by 7 or more species. All of them, however, belong to its subgenus, *Symphysuroides* devoid of a caudal spine. The lower Canadian fauna was enriched in the Cape Clay stage by the appearance of *Helicotoma*, *Clarkoceras* and so forth.

Two younger formations in the region are known by the names of Nunatami and Cape Weber. Merit to POULSEN (1924), *bifidus*, *angustifolius*, gastropod and ostracod zones were distinguished in the Nunatami formation where the first and the second zone were designated respectively by *Didymograptus bifidus* and *Phyllograptus angustifolius*. Judging from these graptolites the age of the Nunatami may be upper Canadian-Llanvirnian.

The fact that the development of the Bathyruridae was accelerated through these four zones can hardly be overlooked. The family is, however, represented in the Cape Weber as well as in the ostracod

zone. The Cape Weber contains *Hystericurus crassilimbatus* POULSEN which ROSS (1951) referred to *Pseudohystericurus*, but there is no hystericuroid in the Nunatami formation. From these facts I contend that the Cape Weber could be at one place partly synchronous with but heteropic from the Nunatami formation at another, although the former is mostly younger than the latter (POULSEN, 1946).

It is most noteworthy that the Bathyuridae, a typical Arcto-American family, are so well represented in these formations by eight genera, namely, *Goniotelus*, *Bathyurellus*, *Jeffersonia*, *Bolbocephalus*, *Petigurus*, *Bathyurina*, *Uronystrum* (*affinis* POULSEN, 1927) and *Goniotelina* (*boggildi* and *crassicornis* POULSEN, 1927). In Northern Europe *Goniotelus* (?) occurs in Trondheim area in Norway, *Petigurus* in Northwest Scotland and *Bathyurellus* (?) in western Ireland (STUBBLEFIELD, 1939). Together with *Piloceras*, *Archaeoscyphia* and some others they reveal the faunal connection along the Caledonian geosyncline in the Canadian epoch. The main route of migration at the time was on the Atlantic side rather than on the Arctic side of North America. The Bathyuridae are distributed in North America from Newfoundland to Alberta through Texas. There is however, none of the family in EVANS' collection, unless *Gonioteloides* or *Lienocephala* is a member. I have not heard of any occurrence of bathyurids further to the north of the Cordilleran geosyncline, except *Bathyurus* (?) which was reported by KINDLE from the Port Clarence limestone of the Seward peninsula.

HINTZE's discovery of *Benthomaspis diminuta* in the J zone of the Pogonip which is congeneric with *B. problematica* from the Nunatami (gastropod zone ?) is of great interest, because it might suggest that the sea connection was still maintained through the Franklin channel, but this trilobite by itself is not sufficiently conclusive evidence of the late Canadian submergence in the Arctic coast of North America. With pygidia only any generic determination of asaphids can hardly be warranted. Judging from the palaeogeography, however, it is not improbable that 2 species of *Niobe* from the Cape Weber formation in East Greenland are emigrants of the *Ceratopyge* fauna at the time of late Canadian inundation.

Actinopeltis and *Ceratopeltis* are two aberrant trilobites indigenous to the Cape Weber sea.

On the basis of the known facts it may be concluded that the submergence was extensive on the west side of Greenland in the

early Canadian, but on the east side after the middle Canadian emergence. The lack of *Kainella* or *Leiostegium* in the Arctic region might be due to the emergence which had commenced already in the late Lower Canadian.

The conclusion on the easterly shifting of the submerged terrain which took place on a grand scale in the circum-Arctic province from early Upper Cambrian to late Lower Ordovician becomes doubly interesting for me when I recall its parallelism as seen in the history of the Dikelocephalidae. In 1936 I pointed out that the Upper Cambrian Dikelocephalinae migrated easterly and developed into the Dikelocephalininae in the early Ordovician period.

The sea connection at the time from Europe to Australasia and Eastern Asia through the Himalayan geosyncline has since been endorsed by more facts on *Asaphopsis* in Tasmania (KOBAYASHI, 1940), *Taihungshania* in New Zealand (1940) and other trilobites in China (1951).

Because the center of distribution of the family was shifted in the same trend as the above mentioned migration of the submerged terrain, there may be a connection between these phenomena in the Arctic and Circum-Arctic regions. The non-ubiquity of epirogeny will be discussed further in the later sections.

B. The Relation of the McKay Faunas to the Atlantic ones

The classical zonation of the Cambro-Ordovician formation in northern Europe can be applied to the contemporary in the eastern maritime province of North America with the least modification. In the recent report by HUTCHINSON (1952), the Upper Cambrian and Lower Ordovician formations in Cape Breton are classified as below.

Table 9. Zonation of the Upper Cambrian and Lower Ordovician Formations in Cape Breton

Formation	Zone	Age
McLeod Brook	<i>Tetragraptus</i>	Arenigian
	<i>Asaphellus-Shumardia</i>	Tremadocian
Mac Neil	<i>Peltura</i>	Late and
	<i>Leptoplastus</i>	Middle
	<i>Parabolinella spinulosa</i>	Olenidian

The contained fauna consists mainly of the Atlantic genera of the Olenidae and Asaphidae. Most of the species are identified with the European ones. *Holasaphus* and *Sphaerophthalmoides* are, however, indigenous genera. The faunal relation to either the Croixian or the Canadian ones is slight.

Beyond the LOGAN'S line there is the North American province and its fauna is quite distinct from that of Cape Breton. Therefore SCHUCHERT considered that the northern Appalachian geosyncline was divided into the St. Lawrence geosyncline on the northwest side and the Acadian geosyncline on the southeast side, intervened by the New Brunswick geanticline. GRABAU, BORN and some others pointed out that such an isthmus ran across the Atlantic during the Ordovician period or Eo-Palaeozoic era. With the recent discovery of fossils, however, it was proven that the metamorphosed axis of the north Appalachian folded mountains is composed mostly of the pre-Carboniferous Palaeozoic rocks.

In the Trondheim district in Norway HOLTEDAHL (1938) and VOGT (1945) have distinguished three important phases in the prorogeny of the Caledonian cycle, namely the Trondheim, Ekne and Horg disturbances which took place respectively in the late Arenigian age, Caradocio-Ashigillian interval and in the early Llandovery age. The symphathetic movement of the Trondheim phase is suggested in the northern Appalachians by the fact that the Cambro-Ordovician sequence terminates in Nova Scotia before the Llanvirnian. The upheavals of the northern Appalachians which yielded the Bald Eagle and Shawang conglomerates on the west side of the elevating land are roughly coeval with the Ekne and Horg disturbances respectively. The peculiar Nappe-like structure of the Green mountains was the product of the Taconic disturbance in which these phases of crustal deformations are incooperated.

In the southern Appalachians it is difficult to point out the boundary between the Gotlandian and Devonian systems in their continuous section. There is no Caledonian discordance in the Appalachians except Newfoundland where some influence of the Caledonian orogeny in the pre-Downtonian *ardennische Phase* or pre-Devonian *erische Phase* is recognized. The Acadian disturbance by which the Catskill delta was produced in New York was undoubtedly the paroxysmal phase in the development of the northern Appalachian geosyncline.

It is questionable whether the axial anticline was so much dissected in the prorogenic stage that it could be the main source of terrigenous material in the geosyncline*. On the other hand it is quite evident that such an embryonic fold was a barrier for migration. If it was an insular arc like the Japanese islands, the difference as seen between the warm Kuroshiwo and the cold Oyashio fauna can be expected on the two sides. In fact such a difference is clearly shown between the Canadian and the Tremadocio-Arenigian faunas in Northern Europe.

If the axial anticline becomes a chain of submarine banks, the faunal difference will not be so well marked between the two sides. It will be the case that the North American elements were mixed with the European fauna at Girvan in Southern Scotland or at Tremore in Southeast Ireland (STUBBLEFIELD, 1939). In the later Ordovician period some actinoceroids had chances to migrate as far as Esthonia (TROEDSSON, 1926, 28, TEICHERT, 1930).

With regard to the tectonic position as well as the faunal boundary the Moine thrust in Northern Scotland is comparable to the LOGAN's line in eastern North America. In spite of the tremendous distance over the Atlantic ocean the faunas in the calcareous veneers on the Laurentian and Lewinsian lands are astonishingly similar to each other. The Canadian faunas in the Durness limestone or in smøla island are quite distinct from the contemporaneous ones in Europe, even when compared with the neritic ones in limestone facies in the Baltic region or even in the Oslo area, notwithstanding the fact that the horizontal distance through the metamorphosed axis is not great.

These tectonic lines were a barrier for stratigraphers in correlating the North American sequence to the classical one in Northern Europe. The sediments of carbonates in the southern Appalachians, Ozark dome and the Cordilleran region were so monotonous that the systematic boundary between the Cambrian and Ordovician was not easy to be drawn. It was thick enough for ULRICH to propose "Ozarkian system" for this part of the Eo-Palaeozoic formation. In North America where the extensive Croixian transgression was followed by the Canadian one the neritic fauna has developed much more than in Europe. Not only in trilobites but also in brachiopods, gastropods and cephalopods greater varieties are met with in the

* A cycle of orogeny is classified into three stages, namely prorogeny, euorogeny, and metaorogeny. (KOBAYASHI, 1952).

Canadian fauna than in the Tremadocian and Arenigian faunas, as shown by ULRICH and his cooperators. The late Croixian and early Canadian ones were combined by ULRICH in his Ozarkian fauna.

In taking the Conchostraca for example (KOBAYASHI, 1954), I have illustrated recently how forcefully orogeny controls the development of land life. Likewise, the rise and fall of marine life is controlled by epirogeny. I think that the difference in the development of marine life between Europe and North America depends upon the difference of epirogeny between the two continents, because this conclusion exactly matches with the known facts in stratigraphy.

The Laurentian Kraton was a land in the early and middle Cambrian periods, but subsequently tilted down on its south side with the result that the Croixian sea flooded over the flat land as far as the great lake district. The pre-Canadian emergence was incomparable with the pre-Chazyan one in magnitude. In consequence the stratigraphic break between the Cambrian and Ordovician systems becomes so slight that it allows ULRICH's proposal of Ozarkian system for the transitional part.

In the Fenno-Russian Kraton on the contrary, the transgression was begun at the Lower Cambrian. The Paradoxidio-Olenidian *Alaunschiefer* is an extensive blanket on the Baltic shield. There is however the pre-Tremadocian break in the Baltic region which becomes larger toward the east till at length in Esthonia the *Obolus appolinista* sandstone at the base of the Ordovician rests directly on the Lower Cambrian *Eophyton* sandstone. This unconformity indicates a tilting of the Kraton which took place gradually but on a grand scale. From the Tremadocian the submergence was renewed and continued through the Ordovician. Accordingly the region was covered by another veneer of sediment. Thus epirogenic movements in these periods are utterly disharmonic and alternate more or less between Laurentia and Fenno-Russia which are the two best known Kratons.

HAUG was the person who pointed out the reciprocal relation of epirogeny between the Kraton and geosyncline. His hypothesis appear to support the fact that while the pre-Tremadocian emergence is well marked in the Baltic region which belongs to the Fenno-Russian Kraton, the Olenidian is represented by the thick *Lingula* Flags in Britain which belong to the Caledonian geosyncline. Because it is generally overlain by the Tremadoc and the more persistent

discordance is found there at the base of the Arenig, the Tremadoc series has been included in the Cambrian system in this country. The submergence of the geosyncline reciprocal to the emergence of the Kraton or *vice versa*,—if this hypothesis is borne out by sufficient number of facts—, must be a factor of prime importance in the evolution and revolution of marine life, because the geosyncline provides the high way for its migration and the epicontinental sea is where it flourishes.

After *Parabolinella evansi* had been described from British Columbia (KOBAYASHI, 1936), *Glyptagnostus*, *Parabolinella* and other Atlantic elements were reported to occur at some places in North America, as recently summarized by WILSON (1954). The distribution map he prepared shows that the Atlantic elements are distributed mostly in the Appalachian, Ouachita and Cordilleran geosynclines on their oceanic sides whereas the North American fauna has flourished in their continental side as well as in the epicontinental sea.

The exotic elements are contained commonly in black mud which facies resembles graptolite shales in lithology. RUEDEMANN (1934) compared the biocoenosis of the graptolite shales or his pure graptolite shales to that of the present Sargass sea which is a sea-meadow where microorganisms are thriving. There may be macroorganisms which prey on them or seek to find shelter. The large ones are nektons, but the small ones are epiplanktons or *paraplanktons*. I wish to propose the latter term for such organisms as trilobites, eurypterids and crustaceans, all without sessil organ, which are vagrant or swimming in the sea-meadow and at the same time floating as far as the current takes them. The discontinuous distribution of pelagic forms is, I think, due much to their paraplanktonic habit. The *Parabolinella* fauna of Purmamarca in Argentina which will be discussed in the next section is in my opinion, mostly composed of such paraplanktons.

Because the exotic elements are keys to the interprovincial correlation, it will be of special value, if any Atlantic element is found in the Canadian sediments. It was as early as 1877 that WHITE described *Megalaspis belemnurus*. The generic name suggests its being a Baltic trilobite, but it is known now to be the type species of *Xenostegium*. In his paper on the *Ceratopygokalk*, BRÖGGER (1896) has pointed out that *Dicellosephalus finalis* WALCOTT is *Apatokephalus* which was thought then to be a characteristic genus of the Cera-

topyge fauna. Later, however, *finalis* was selected by RAYMOND (1937) for the type of *Diplapatokephalus* which is indigenous to North America and *Apatokephalus* is known now as a cosmopolitan genus. In 1921 WALCOTT described *Ceratopyge canadensis* from the Goodsir formation in British Columbia, but as pointed out by RAYMOND (1932), it is congeneric with *Housia varro*.

In discussing the *Ceratopyge* fauna in western North America RAYMOND called attention to the inclusion of *Symphysurus* and *Hemigyraspis* in the Canadian fauna, but they were found later to be distinct from the suggested genera and *Symphysurina* and *Bellefontia* were instituted by ULRICH for them (1924). No trilobite has as yet been discovered from the Canadian sediments which can safely be referred to *Ceratopyge*, *Niobe* or *Euloma*, although *Pareuloma* from Newfoundland (RASETTI, 1954) and *Eulomella* from British Columbia appear to be related to *Euloma* closely.

For the interprovincial correlation, especially interesting is the faunule of the *Symphysurina* limestone from loc. 19. It contains *Parabolinella bisulcatus* in addition to *Jujuyaspis borealis* and *Sphaerophthalmella inexpectans*, all of which are derivatives of the Olenidae. *Eobucania pulchra* also contained in this faunule reveals the typical aspect of the Bucaniidae which are unknown from the Cambrian sediments (WENZ, 1938).

In Sweden *Parabolinella* appears in the subzone with *Peltura scaraboeoides acutidens* and *P. minor* of the *Peltura*, *Sphaerophthalmus* and *Ctenopyge* zone (5_b) (WESTERGÅRD, 1922), and persisted through the *Ceratopyge* stage from the *Dictyograptus* zone to the *Apatokephalus* zone. In the Mjøsen district, Norway, it survived no longer than the *Ceratopyge* shale (3_{ab}). *Jujuyaspis* is an important member of the *Parabolinella* shale in Argentina. Therefore the coexistence of *Symphysurina*, *Parabolinella* and *Jujuyaspis* would be proof of the synchronism of the lowest Canadian to the lower Tremadocian and also the *Parabolinella* shale of Northern Argentina.

Peltura pacifica which occurs at locs. 9 and 20 is another emigrant from the Atlantic province. In Sweden *Peltura* appeared almost simultaneously with *Parabolinella*. If the "*Peltura*" *punctata* beds in Carmarthenshire which contains a relict Tremadoc fauna in the Arenig shaly facies is excluded, the vertical range of *Peltura* in Northern Europe does not extend beyond the Tremadocian. In the Mjøsen district, it dies out in the 3_{aα} stage, i.e. the lower division of

the *Ceratopyge* shale. Because *pacifica* is found associated with an indeterminable Nileidae at loc. 9 and with *Apatokephalus* and two asaphids at loc. 20, the age of the faunule must be early Ordovician. Therefore this can be said to be another fact bearing on the correlation of the Tremadocian to the lower Canadian.

In my opinion *Cyrtometopus primigenius* ANGELIN from the *Apatokephalus* and *Shumardia* zones in Sweden is the typical member of *Protopliomerops*. As it is a late Tremadocian species, it is older than those of the genus in western North America. Several species of *Protopliomerops* are known from the G₁ zone of the Garden City, from the G₁ to H zones of the Pogonip and in the McKay group in which it is accompanied by *Kirkella*. They as a whole reveal a greater development of the genus in the Cordilleran trough after *primigenius* died out in the Baltic region.

A few words are added here to *Macropyge* and *Asaphelina*, although they are not known from the McKay group. The former genus was established on the basis of *M. chremi* from the Shineton shale. *M. gradiator* from the G₂ zone of the Garden City is a little younger than the British Tremadocian species.

Asaphelina (?) sp. was collected by Ross at Twin Bridges Dugway in Long Canyon, Utah in a black shale which contains graptolites probably younger than the Schaghticoke fauna. Ross states that *Receptaculites* is abundant immediately above the graptolite shale. Incidentally it is known in the Pogonip that *Receptaculites* is common in the M zone. It is unfortunate that the cephalon of the trilobite in question is unknown, but the great similarity of the other parts of the trilobite to *Asaphelina barroisi* can hardly be overlooked. This occurs commonly in the upper Tremadocian and rarely in the lower Arenigian in Southern France.

From the above statement it may be understood that *Protopliomerops*, *Macropyge* and probably *Asaphelina* (?) in the Cordilleran province are all homotaxial to those in Northern or Southern Europe.

Finally the find of *Telephus* at loc. 10 is extraordinarily interesting because the known distribution of the genus extends from the Southern Appalachians into Scandinavia and Bohemia through Quebec, Newfoundland and the Scotts-Irish area. In Europe it occurs in the Ordovician sediments, Llandeilian and younger. In Newfoundland it is known from the N and P divisions. In the Southern Appalachians it is represented by many species from the upper Chazyan Blount

formation which includes the Tellico formation, Athens shale and Whitesburg limestone by ULRICH.

C. The Relation of the McKay Faunas to the Andean ones

Parabolinella andenica and some other trilobites described from South America by KAYSER, HOEK and LAKE revealed the Atlantic aspect of the Eo-Palaeozoic fauna, but there have been none typical of the North American fauna. Therefore I was struck by the find of *Kainella* which was collected by KEIDEL from Prairie Catamarca as well as *Leiostegium* and a hystricuroid procured by BROWN from Cajas, Argentina (KOBAYASHI, 1934, 36). The coexistence of these trilobites shows that the South Andean fauna is invaluable in determining the Cambro-Ordovician palaeogeography and interprovincial correlation.

Stimulated by these discoveries I have carried out a revision on some old collections of the shelly faunas in the continent (1937). Subsequently the Lower Ordovician faunas of northern Argentina were investigated by HARRINGTON in great detail and the result was published in his monograph (1938). At that time our knowledge of the Cambrian faunas was still meager. Later, however, HARRINGTON and LEANZA (1943) have described *Amecephalina*, *Eteraspis* and *Ehmania* from Quebrada de Laja and Quebrada de Juan Pobra in San Juan province and pointed out the affinity of the faunule with the Maryville fauna of the late Albertan age.

Another Middle Cambrian faunule which LEANZA (1947) described from Quebrada de San Isidro comprises *Kootenia incerta* (RUSCONI), *Clavaspidella digesta* LEANZA, *Zacanthoides ferula* LEANZA and *Amecephalus mendozanus* (RUSCONI) and bears also the Albertan aspect, but older than the preceding.

The Cambrian fauna of South Andes was further amplified by RUSCONI (1951, 52, 53) with the material from Mendoza region. A few of the significant members he described are as follows:

1. *Goniagnostus*.
2. Irvingellid.
3. *Hungaia* (?) *puelchana* having two pairs of strong pits on the glabella and the eyes fairly apart from the glabella.
4. *Vinakainella* closely related to *Oryctocephalus*.
5. *Chilometopus* resembling *Poliella*.

Thus the Cambrian fauna of the Southern Andes is closely

related to the Albertan and Croixian ones. *Goniagnostus* is, however, so far restricted to the Paradoxian (*dauidis* and *forchhammeri* zones).

My conclusion that the Lower Ordovician fauna of South America is an admixture between the Atlantic and North American elements was thoroughly endorsed by HARRINGTON.

The Lower Ordovician fossils of North Argentina was classified by him into the following 5 assemblages:-

<i>Kayseraspis</i> faunaLower Arenigian
<i>Triarthrus</i> fauna	} Upper Tremadocian
<i>Asaphellus</i> fauna	
<i>Parabolinella</i> fauna	} Lower Tremadocian
<i>Kainella</i> fauna	

There is, however, no section where the superposition of the *Asaphellus* on the *Parabolinella* beds can be determined. After studying the correlation table given by HARRINGTON, I feel that more remains to be done in the field, before the faunal succession is thoroughly established stratigraphically.

The Tremadocian fauna of Argentina comprising over 10 genera of the Olenidae is rich enough to be called "Meta-Olenidian fauna." in the Tremadocian epoch the center of distribution appears to have shifted from the Atlantic to the Southern Andean region where *Olenus*, *Protopeltura*, *Parabolina* and a few other relicts still survived. In addition there appeared such endemic genera as *Jujuyaspis*, *Mekyrophyrs* and so on.

The Shumardiidae and Ceratopygidae are also well represented in the Andean fauna. The inclusion of *Orometopus* in it is indeed a remarkable fact, because insofar as I am aware, the genus is typical of the true Tremadocian fauna. *Apatokephalus* is a cosmopolitan genus, but it is noteworthy that two species, *serratus* and *dubius*, are found in Argentina.

Protopliomerops is represented there by two or three species one of which is identified with Baltic *Cyrtometopus primigenius*. In addition *Metapilekia* is known from the upper Tremadocian and *Pilekia* from the lower Arenigian. They as a whole are linked with the cheinuroids in western North America where they developed in the middle and upper Canadian.

As links between the faunas of Americas the more important are *Kainella*, *Leiostegium* and *Hystericurus* all of which are unknown in the Atlantic province. The Kainellidae were not less developed in

South America than in North America.

Leaving some endemic genera out of consideration, it can be said with confidence that the fauna of the southern Andes is closer to the Tremadocian than to the lower Canadian fauna.

The *Kayseraspis* fauna which HARRINGTON considered early Arenigian is the next younger. *Thysanopyge* in it is an indigeneous genus. While *Megalaspis* suggests its connection with the Baltic fauna, *Pilekia* reveals its alliance to the North American one. It is worth while to note that there are some asaphids in the McKay group which look very similar to *Kayseraspis*, although the specimens at hand are too fragmentary to warrant the identification.

In my opinion the *Hoekaspis* fauna is younger than the *Kayseraspis* fauna and most probably late Arenigian in age. It contains *Synhomalonotus* (?) *pompeckji* and *Trinucleus krugeri* which the latter is allied to *Cryptolithus ornatus*, a leading member of the *Synhomalonotus tristani* fauna. *Synhomalonotus* is unknown in North America and Northern Europe, if its temporary invasion into Britain in the Arenig is overlooked. The *tristani* fauna has flourished in Southern Europe as far as the transgression of Grés Armorican was expanded.

As a result of studies of GIGOUX (1951) it was found that the fauna is distributed further to the south into the Atlas in North Africa.

I wish to call attention here to the fact that *Lachnostoma* (?) sp. from loc. 13 is allied to *Lachnostoma* on one side but to *Hoekaspis* on the other, although the true relationship must be decided with better material.

Thus the Lower Ordovician faunas of the southern Andes are related to the Canadian ones in one way or another. It is, however, a remarkable distinction that *Symphysurina* which is prevalent in the Arcto-American province is totally absent in South America. The question then is whether the *Kainella* faunas of Americas are contemporaneous with each other or whether the *Kainella* fauna in the south is contemporaneous with the *Symphysurina* fauna and homotaxial to the *Kainella* fauna in the north. At the same time my problem is whether the *Parabolinella* fauna is really younger than the *Kainella* fauna.

Because I have not actually seen the fossil occurrence, I wish to look into the relation of the fauna to their mother rocks by my personal observation on the old fossil collections and also from HARRINGTON's

description.

1. Most significant among various facies is the black shale or slate (*Pizzara negra*) containing *Parabolinella*, *Jujuyaspis* and other Olenidae as the leading components of the fauna; *Dictyonema* happens to occur in them. The carbonaceous black shale of Purmamarca is the typical example.

2. Dark gray or variegated shales containing the *Parabolinella* fauna with *Pseudokainella* or the *Asaphellus* fauna with *Kainella*.

3. *Kainella* appears, however, more common in sandstones than in these shales.

4. Limestones at Humahuaca and a few other places yield *Leiostegium* and others, but *Leiostegium* is found also in sandstones.

5. Cheiruroids are contained mostly in gray or vari-coloured shales and sandstones, upper Tremadocian or lower Arenigian.

6. The *Hoekaspis* fauna which I described was in chocolate shales and red quartzite. *H. schlafintweiti* is described by HARRINGTON and LEANZA (1943) from a gray limestone in the Sierra de Zapla, Jujuy.

In looking through these rocks and the contained faunas the fact that there is some parallelism between the lithofacies and the fossil-coenosis when limestone and varicoloured shales are interposed between sandstones and black shales must be acknowledged. Therefore it is probable that the difference among the four Tremadocian and two Arenigian faunas implies not only a time difference but also a difference of environment. Accordingly a fauna could be partially contemporaneous with another which is thought to be older or younger.

In the *Parabolinella* shales the spiniferous Olenidae, in about 10 species, are widely distributed and form the principal part of the fauna. *Pseudokainella*, also spiniferous, occurs at two localities, while *Asaphellus* and *Illænus* are each found only at one locality. The other trilobites are *Shumardia* and *Geragnostus*, both small and cosmopolitan, *Obolus*, *Lingula* and *Ctenodonta*, one species in each genus, are found only in the *Pizzara negra* of the Rio Valcancito. *Ctenodonta famatinensis* is a diminutive form, 4.5 mm. by 3.5 mm. Two atremate brachiopods are listed but undescribed. Those with peduncles could have been epiplanktons and others paraplanktons as defined in the preceding section. Although *Dictyonema* is not always contained in the shales, I venture to say that like the pure graptolite shales, the *Parabolinella*-bearing black shales are probably

off-shore sediments.

I once suggested late Upper Cambrian for the *Parabolinella* fauna, and it is really more related to the late Olenidian than to the Tremadocian fauna in the Atlantic province. In fact about a half of the Olenidae, namely *Ctenopyge*, *Cyclognathus*, *Parabolina* and *Protopeltura*, are Olenidian genera unknown in the Tremadocian of Europe. Such Ordovician elements as *Asaphellus* and *Iliaenus* are rather accessories in the fauna.

The Rio Volcancito in la Sierra de Famatina is the only place where the fauna is found together with the *Kainella* fauna. As it is such a crucial point it requires a reexamination of the zonation in Provincia of La Rioja. If the stratigraphic observation admits an upset of the zonation, it will be much easier to explain the change in the faunal aspect. If so modified, the *Parabolinella* zone in the south will be recognized to be an approximate equivalent to the *Symphysurina* zone. The tentative correlation is shown in table 10.

Table 10. Correlation of the Ordovician Faunas in the McKay Group to the Fossil Zones in the South Andes.

McKay Group.	South Andes
<i>Kirkella</i> fauna	<i>Hoekaspis</i> zone
<i>Kobayashia</i> faunule	<i>Kayseraspis</i> zone
<i>Ozarkispira</i> faunule	<i>Triarthrus</i> zone <i>Asaphellus</i> zone
<i>Kainella</i> fauna	<i>Kainella</i> zone
<i>Symphysurina</i> fauna	<i>Parabolinella</i> zone

As I have summarized in my monograph (1937), the shelly faunas are extensive in western and northern Argentina and in the southern plateau of Bolivia. Recently HARRINGTON and KAY (1951) reported the occurrences of the Cambro-Ordovician fossils from eastern Columbia as follows:

1. *Dichograptus-Tetragraptus* shale (Arenigian)
2. *Megalaspis* cfr. *planilimbata* shale (Upper Tremadocian)
3. *Kainella* limestone (lower Tremadocian)
4. *Ehmania* limestone (upper Albertan)

From the litho- and bio-facies GERTH (1932) has classified the

Ordovician formations in South America into (1) the graptolite shale facies, (2) the mixed facies of shale and sandstone and (3) the limestone-dolomite facies. The best display of the graptolite facies is found in Peru (BULMAN, 1931). LEITH (1938) described *Dicranograptus caparroensis*, *Cryptolithus terryi* and a few other fossils from a metamorphosed shale of the Caparro-Bellavista series in the state of Barinas (i.e. Zamora) in the Venezuelan Andes and suggested the Normanskill-Glenkiln-Lower Hartfell time for the age of the faunule chiefly for the reason that the new graptolite is allied to *Dicranograptus ramosus* (HALL). Lately WHITTINGTON (1954) referred the trilobite to *Onnia* and noted the faunal connection from central Europe and North Africa to northern South America in the Middle Ordovician period.

Because the *Parabolinopsis*-bearing black shale of Salitre and the *Parabolinella*-bearing black shale of Purmamarca are similar to the graptolite shales in lithology, the line on which these points are connected with Zamora through eastern Peru may reveal *the axis of the Andean geosyncline in the early Ordovician period*.

Because the trans-Atlantic elements are especially rich in the black mud facies, the axial zone of the geosyncline is thought to have been the route of their migration from Europe to the Andes. The Appalachian geosyncline must have been en route, because this kind of the fauna is known from Cape Breton.

While the Andean fauna is allied to that of Northern Europe in the Tremadocian epoch, the late Arenigian *Hoekaspis* fauna is related to the Mediterranean fauna. With regard to such an Atlantic connection it is noteworthy that *Colpocoryphe excul* (WHITTINGTON, 1953) is described from the early Middle Ordovician rocks of Florida and the occurrences of *Onnia* reported from the Caradocian and (?) Llandeilian in Morocco. (TERMIERS, 1950). The question is, however, just where was the trans-Atlantic connection maintained at the time?

Because of the common occurrence of *Kainella* and *Leiostegium* it is undeniable that the Canadian sea was confluent with the Andean sea. The faunal affinity between the two sides can be seen regardless of the facies and the connection was probably maintained even in the *Hoekaspis* hemera, if *Lachnostoma* (?) sp. is really related to *Hoekaspis*.

D. A brief Note on the Relation of the McKay Faunas to the Western Pacific ones

This note is limited here to the extent that it is enough to analyse the MaKay fauna, because I expect to discuss the matter thoroughly with the Korean fauna at the focus, when the remaining part of my monograph on the Cambro-Ordovician faunas of South Korea is brought to completion.

No *Symphysurina* has so far been found in Eastern Asia. Its resemblance to *Tsinania* may be superficial. As has been discussed elsewhere (1952), *Tsinania* is probably related to *Mansuyia*. *Illaeonurus ceres* by MANSUY (1916, non WALCOTT), i.e. *Dictyella* (?) *mansuyi* KOBAYASHI has a pygidium of *Symphysurina* type, but the cranidium shows that it belongs to the Tsinanidae. Its age must be late Upper Cambrian because it occurs in association with *Prosaukia angulata*.

As summarized in my recent paper (1953), the Kainellidae are well represented in Eastern Asia by several species in *Kainella*, *Pseudokainella*, *Apatokephalus* and *Hukasawaia* from South Korea in addition to *Kainella primigena* from the Sino-Tonkin border. Furthermore it is noted here that *Bathyurus jenchangensis* CHANG (1949) from the *Dictyonema*-“*Asaphellus*” zone of the Yehli formation in Kaiping basin, Hopeh has a cranidium which looks to me to be more similar to the Kainellidae, especially to *Pseudokainella*, than to the Bathynridae, although its illustration is not clear enough to be more definite.

Hystriuroids are reported from the Yehli formation in Hopeh, Wuting formation in South Manchuria, (ENDO, 1935) and from the *Clarkella* zone in South Korea.

In South Korea the *Asaphellus* zone is the lowest fossil zone of the Ordovician formation. The next is the *Protopliomerops* zone where *Dikelocephalina* and *Apatokephalus* were collected. The third is the *Clarkella* zone which contains *Pomatotrema*, *Hystriurus* and several Asaphidae resembling *Megalaspis* and “*Xenostegium*.” Some of them look very similar to *albertensis*, *douglasensis* and *euclides* of *Xenostegium*, s.l., but none is sufficiently well preserved to permit an exact identification. “*Plethopeltis*” *ulrichi* is not *Plethopeltis* but belongs more probably to the Bathyruridae than to any other family. *Leiostegioides* is closely allied to *Leiostegium*. It can safely be concluded that the *Clarkella* fauna is on the whole intimately related to the Canadian fauna. Finally, so far as the Ordovician trilobites are

concerned, the Australasian fauna is distinct from the North American one, but there is *Carolinites*. It was first described from Caroline Creek, near Latrobe, Mersey river district, in Tasmania (KOBAYASHI, 1940), and later its occurrences were found in the Arenig of Ireland (STUBBLEFIELD, 1950), the J zone of the Garden City (Ross, 1951) and the F to the M zone of the Pogonip (HINTZE, 1952). Such a discontinuous distribution is extremely difficult to explain, unless more is learned of its occurrences.

Chapter IV.

Summary and Conclusion

The part of EVANS' collection from the McKay group which is dealt with in this paper contains a copious Ordovician fauna in which trilobites are most abundant. The collection was made from various places in the Columbia river valley. Six fossil localities are in the McKay creek, 3 of which are exactly allocated in the type section and the horizons of the three others also suggested in table 2.

Although little is known of the stratigraphic relation among the other localities, some ten assemblages can be distinguished in the Ordovician collection from the fossil association, namely, the *Symphysurina* fauna, *Robsonoceras*(?), *Apatokephalus* and *Peltura* faunules, *Evansaspis-Kainella* fauna, *Lingukainella* faunule, *Ozarkispira* faunule, *Kobayashia* faunule, *Kirkella-Protoptomerops* fauna and the *Telephus* faunule.

The time relation of these faunas is thought to be in the above mentioned order, because as shown in table 7, most of them can be correlated to the zones of the Pogonip and Garden City formations in Utah and Nevada with some accuracy. With the find of *Telephus* in the collection from loc. 10 it can be concluded with confidence that the top of the McKay group is as high as upper Chazyan.

These faunas and faunules are tentatively correlated to the zones cited in EVANS' report (1933) and shown in table 8. In my opinion all of the faunas except the *Telephus* faunule belong to the Canadian. The aspect of the Canadian faunas is, however, fairly different between those older and younger than the *Ozarkispira* faunule. It is especially remarkable that several relicts of the Cambrian trilobite families are contained in the older ones. Nevertheless, the *Symphysurina* fauna which is the oldest of them, is not Cambrian, because the Asaphidae are usually well represented in the fauna which was distributed extensively in the Arcto-American province and because the typical Bucaniidae are included in the faunas of the McKay group and also of the Tribes Hill in New York. Therefore I do not hesitate to draw the systematic boundary within the Mons formation between the *Briscoia* and *Symphysurina* zones.

We must not however, overlook the fact that the upper Croixian,

or the *Briscoia* zone was combined with the Canadian zones or beds in a stratigraphic unit called Mons. It means that there is no distinct change of lithology through the Mons. Likewise the systematic boundary appears to be not so sharp in the Pogonip group in Nevada because its lower part belongs to the Croixian.

As may be understood from the ULRICH's proposal of the Ozarkian system, the emergence at the transition between the Cambrian and Ordovician periods was not great in North America on the whole. Marine life has flourished in the epeiric sea there much more than in Europe. A greater variety of relicts which are thought to belong to the Cambrian trilobite families survived. The Solenopleuridae rejuvenated yielding various kinds of hystricuroids. Several genera of the Asaphidae which are characteristic of North America also appeared. In the wealth of brachiopods, gastropods and cephalopods the Canadian fauna far exceeds the contemporaneous fauna in Europe. It is not too much to say that the history of organic evolution in this part of the Ordovician period is better recorded in the Canadian than in any classical section in Northern Europe. From this viewpoint an intensive research in the McKay group or the Mons formation in which the Canadian is combined with the Upper Croixian is of special value.

From the standpoint of distribution the Canadian trilobites in the McKay group may be classified as follows:

1. Cosmopolitan genera or genera distributed widely in many provinces.
2. Genera of interprovincial distribution or those distributed in two or a few neighbouring provinces.
3. Provincial genera or those prevalent in a province.
4. Local genera or those indigenous to a small restricted part of a province.

For example *Apatokephalus* is a cosmopolitan, but the distribution of *Diplapatokephalus* is restricted to North America. *Symphysurina* and *Leiostegium* are two interprovincial genera, but the former is distributed from North America to the Arctic province, whereas the latter is spread from North America into the Andean province. The widely distributing ones are, if their vertical range is limited, very important for the interprovincial correlation and those of the Olenidae especially important for the correlation of any sequence to the classical one in Northern Europe. Therefore the finding of such

genera as *Parabolinella* and *Peltura* is an invaluable factor in determining the age of the McKay group. In view of the inclusion of these olenids and also of the Cambrian relicts, I think it appropriate to correlate the Canadian faunas older or younger than the *Ozarkispira* faunule to the Tremadocian or Arenigian respectively.

Some of the interprovincial genera are short ranged, but some others are long ranged. When the latter kind of trilobites develop in a region after declining in another, the trilobites in the two regions are homotaxial, instead of synchronous. It is the relation of *Protopliomerops* in the Cordilleran province to that of Scandinavia.

Insofar as the prosperity is judged from the number of genera, it is a striking fact that the Olenidae have flourished in the early Tremadocian epoch more in the Andean province than in the Atlantic provenance. In my opinion the *Parabolinella* shale in North Argentina is probably equivalent to the *Symphysurina* limestone of the McKay group not only because *Jujuyaspis* occurs in both of them but also because the two agree in the inclusion of Cambrian relicts. The *Kainella* fauna of Americas are accordingly nearly contemporaneous with each other. The Caledonian and Appalachian geosynclines are thought to have been the highway for the Olenidae to migrate into these provinces. There the emigrants of the family developed endemically. *Mekyrophrys* and *Sphaerophthalmella* are examples of such local genera born respectively in the southern Andean or the northern Cordilleran region.

As has been noted elsewhere, the center of distribution of the Dikelocephalidae was shifted easterly. It was an Asiatic-North American family in the late Cambrian, but became a western Pacific-European one in the early Ordovician period. It is an interesting coincidence that the distribution center of the Leiostegiidae was shifted in the same trend simultaneously. In the early Upper Cambrian period the *Koldinia* fauna was in Northern Eurasia and the *Chuangia* fauna was spread in Southern and Eastern Asia, while in the Lower Ordovician *Leiostegium* was distributed widely in North and South America. *Leiostegium* is linked with *Chuangia* by *Chuangiella* in the *Briscoia* fauna of Alaska.

I wish here to call attention to the fact that the marine transgression has shifted easterly from one region to another in the Arctic province as clearly demonstrated by fossil evidence. It has taken place simultaneously with the easterly shifting of these

families. Is such a coincidence merely accidental?

Of course much still remains to be learned of the behaviour of the earth movements that are termed orogeny and epirogeny before their habits can be theorized. It is, however, readily proven in Eurasia that the former is not ubiquitous. Namely, the cycles of the Caledonian and Variscan orogenies have taken place on the west side of Eurasia during the Palaeozoic era. The Mesozoic was more quiet in Europe, although the post-Permian movements are grouped in the Alpine cycle of orogeny by STILLE. The reverse is the case in Eastern Asia. The Mesozoic was a much more mobile period than the Palaeozoic. In the Japanese and other festoon islands the Permo-Triassic cycle of the Akiyoshi orogeny and the Jurassic-Cretaceous cycle of the Sakawa orogeny took place (KOBAYASHI, 1941). Their paroxysms were in the middle Triassic and in the early Cretaceous. Almost simultaneously with these movements the *Chinese Heterogen* was strongly disturbed. These disturbances are called Shorin and Yenshan (KOBAYASHI, 1953).

The rise and fall of life are inseparable from the movements of the crust on which it flourishes. Land life is more related to the orogeny than to the epirogeny and the reverse is the case of marine life. Taking the Conchostraca for an example, I have recently demonstrated how close mutual relation is (KOBAYASHI, 1954). They are really Palaeozoic Crustaceans in Europe but Mesozoic ones in Asia. This is because the center of the distribution was shifted from the west to the east, caused by the shifting of the orogenic cycle from the Caledonian-Variscan to the Akiyoshi-Sakawa. It is quite probable that the shifting of the distribution-center seen in the two trilobite families is related intimately to the shifting of epirogeny clearly seen in the Arctic province.

The typical epirogeny or the epirogeny in the strict sense is a crustal movement which takes place on the Megakraton through a prolonged geological period. Because of its slowness and extensiveness it is very difficult to point out the epochs of the maximum emergence and submergence. Therefore any conclusion deduced for the epirogeny can easily fall into fallacy, unless the zonation in each province is done with great accuracy and such zones obtained from various provinces are correctly correlated with one another.

A comparison of the Cambro-Ordovician history between Laurentia and Fenno-Russia, however, has shown that the epirogeny in dishar-

monic and more or less alternating between them. The crustal movement is also disharmonic or more or less reciprocal between the Fenno-Russian Kraton and the Caledonian geosyncline.

Because the boundary of a period or an era is marked off by a revolution of marine life on a world-wide scale, epirogeny which causes such a revolution must be also ubiquitous, but epirogeny may not be literally ubiquitous, if it is examined with great accuracy. The relation of the epirogeny in the Kraton to the cycle of orogeny in the geosyncline may be more complicated. The evolution and revolution of the biosphere which depend upon the multiple factors of the bios in themselves as well as various geological phenomena are far more complicated. Nevertheless it is interesting to see a certain parallelism between the epirogeny and the development of marine life.

Chapter V.

Description of Fossils

Putting aside brachiopods* and graptolites there are some 70 Ordovician forms in EVANS' collection from the McKay group in British Columbia, most of which belong to Trilobita, but a part to Mollusca. About a third of them is, however, so poorly preserved that no exact identification can be made. There are some 40 new species which are described in this paper. The followings are new genera, subgenera and subfamilies which are instituted on this occasion.

Symphysurinae, nov. in Asaphidae BURMEISTER

Eulominae, nov. in Ptychoparidae MATTHEW

Eobucania, nov. (Type species: *Eobucania pulchra*, nov.)

Evansaspis, new subgenus of *Leiostridium*, (*Leiostridium* (*Evansaspis*) *glabrum*, nov.)

Columbicephalus, nov. (*Columbicephalus macrops*, nov.)

Gonioteloides, nov. (*Gonioteloides monoceros*, nov.)

Eulomella, nov. (*Eulomella mckayensis*, nov.)

Neotaenicephalus, nov. (*Neotaenicephalus obsoleta*, nov.)

Vermilionites, nov. (*Vermilionites bisulcatus*, nov.)

* Dr. G. Arthur COOPER of the U. S. National Museum, Washington, D. C. has kindly examined the brachiopods in EVANS' collection and informed me of the following result for which I am very grateful. The trilobite fauna at each locality is cited in the list in brackets according to my classification.

Loc. 2=Lower Canadian=Mons. (*Kainella-Evansaspis* faunule).

Syntrophina convexa KINDLE

Finkelburgia sp.

Loc. 4=Upper Cambrian or Lower Canadian. (Asaphid faunule).

Obolus sp.

Loc. 16=Age? (*Symphysurina* faunule).

Lingulella? sp.

Loc. 17=Upper Canadian. (*Kirkella-Protopliomerops* faunule).

Archaeorthis? sp.

Loc. 21=Upper Canadian. (*Kirkella-Protopliomerops* faunule).

Archaeorthis sp.

Loc. 22=High Cambrian or Low Canadian, probably the latter, (*Symphysurina* faunule).

Apheorthis sp.

Loc. 23=Lower Canadian=*Nanorthis* zone=Mons. (*Symphysurina* faunule).

Nanorthis putilla (WALCOTT)

Loc. 24=Lower Canadian=Mons. (*Symphysurina* faunule).

Glyptotrophia jasperensis (KINDLE)

Apheorthis ocha (WALCOTT)

Metabowmania, nov. (*Metabowmania latilimbata*, nov.)
Macroculites, nov. (*Macroculites enigmaticus*, nov.)
Sphaerophthalmella, nov. (*Sphaerophthalmella inexpectans*, nov.)
Lunacrania, nov. (*Lunacrania trisecta*, nov.)
Rhampophyge, nov. (*Rhampophyge altipolum*, nov.)
Neoagnostus, nov. (*Neoagnostus aspidoides*, nov.)
Hyperagnostus, nov. (*Hyperagnostus binodosus*, nov.)

Phylum Mollusca

Class Gastropoda

Beside those below described there are an indeterminable form from loc. 5 and another from loc. 13 in the collection at hand.

Genus *Eobucania* KOBAYASHI, new genus

Diagnosis:—Spire composed of a few volutions, plani-spiral, closely coiling and rapidly expanding; slit-band only slightly elevated and carinated on each side; dorsal lip sinuated forming an acute V; last whorl somewhat flared near the apertural margin; surface marked with transversal, non-lamellose, fine numerous striae.

Type species:—*Eobucania pulchra* KOBAYASHI, new species.

Remark:—This genus is considered to be a member of the family, Bucaniidae ULRICH and SCOFIELD. It is similar to *Zonidiscus* SPITZ of which *Cyrtolites discus* LINDSTRÖM (1884) is the type, but the growth of the shell is more rapid. Its whorl is not so compressed and its dorsal side not so much protruded along the slit-band as in that genus.

Distribution:—Lower Ordovician; western Canada.

Eobucania pulchra KOBAYASHI, new species.

Plate I, figures 1a-f.

Description:—Spire composed of two or more volutions which are just in contact with one another and very rapidly expanding; slit-band a little concave, narrow, slightly elevated and sharply defined by a narrow carina on each side; flank gently convex as far as an obtuse lateral angulation where the whorl is broadest; then the flank inclined toward the umbilicus with stronger convexity; striae on the

surface fine, dense, numerous, somewhat wavy, and remarkably arcuate with convexity on the adoral side; their intervals nearly as wide as the striae; on the slit-band the striae convex toward the apex; shell somewhat flared near the aperture; oral margin parallel to the striae except the dorsol lip where the margin is deeply incised in form of V.

Observation.—Due to secondary deformation a flank not illustrated is partly broken and depressed. The position and strength of the lateral angulation are also somewhat different between the two sides. Judging from the slight flaring near the aperture, this is undoubtedly a grown form, if not a full-grown one.

Comparison.—This species resembles *Bucania cyrtoglypta* HARRINGTON (1938). In that species, however, the spire is composed of 3 or 4 volutions and the ridges on the flanks are much coarser than the striae and not so densely distributed as in this species. The slit-band appears somewhat broader and the whorl section more rounded in that than in this species.

In the whorl section and fine ornamentation its similarity with *Bellerophon subovatus* CLELAND (1909), from the Tribes Hill of New York is so great that the two are thought to be possibly congeneric. Unfortunately, however, the rough sketch and brief description of *B. subovatus* do not admit any precise comparison.

Bellerophon(?) norvegicus BRÖGGER (1882) from the lower *Ceratopyge*-kalk (3_{av}) looks also very similar to this in the lateral view, but the sinus is shallower and the slit-band not so well developed as in this species.

Occurrence.—The holotype from loc. 19; a specimen from loc. 18.

Genus *Raphistomina* ULRICH and SCOFIELD, 1897

Raphistomina sinclairiensis KOBAYASHI, new species

Plate I, figures 2a-c, 3.

Description.—Shell discoidal; spire very low, composed of 4 or more volutions, dextral when seen from the flat side; whorl section sublenticular; top plane slightly convex, a little depressed along the suture below the plane of the preceding volution; periphery acutely angulate; lower wall much more steeply inclined on the umbilical than on the other side; umbilical wall subvertical; umbilicus very deep and half as wide as the last whorl.

The upper wall is a little more convex in the inner than in the outer volution. The largest specimen has the diameter of 24 mm.

Comparison.—There are four specimens from loc. 5, but none shows growth lines. In some of them a narrow depressed band is seen along the periphery of the last whorl.

Raphistoma lapicida SALTER and *Rotellomphalus tardus* PERNER are the type species respectively of *Raphistomina* ULRICH and SCOFIELD, 1897, and *Rotellomphalus* PERNER, 1903, and the latter genus considered a synonym of the former by SHIMER and SHROCK (1947). This species is very similar to them and intermediate between them in the expansion of the spire. The umbilicus appears broader in this than in *lapicida*. The peripheral band is not so clearly seen in these species.

Like this species *Raphistoma parvum* STAUFFER (1937) from the Shakopee dolomite in Minnesota has a very low spire. It coils more rapidly and has 4 or 5 volutions notwithstanding that its diameter is a fifth or so of this species. *Raphistomina latiumbilitata* POULSEN (1927) from the Nunatami formation of Northwest Greenland is quite distinct from this species in the much broader umbilicus and the median angulation on the lower side.

Occurrence.—Loc. 5.

Raphistomina sinclairiensis var. *acuta* KOBAYASHI, new variety

Plate I, figures 4a-b.

There are three specimens from loc. 2 which are closely allied to the preceding but the peripheral angle is evidently sharper and the convexity of the basal plane quite reduced. Such a form is here distinguished from the preceding as a variety, *acuta*.

Occurrence.—Loc. 2.

Genus *Burnesella* BRIDGE and CLOUD, 1947

Burnesella tympama KOBAYASHI, new species.

Plate I, figures 5a-c.

Description.—Shell medium in size, discoidal with a nearly flat base; spire planispiral, a little depressed and composed of 4 or more volutions; whorl subquadrate in cross section; upper wall slightly

concave, elevating toward a prominent but round topped peripheral carina; outer wall gently convex, steeply slant and abruptly bent inward near the base; basal wall also gently convex and more or less inclined inward; umbilicus large, wide open and slightly depressed; suture deep; aperture sinuate in form of V; surface smooth.

Observation.:—This is represented by a specimen, 17.5 mm in diameter and 6 mm high near the aperture. Although the apertural margin is partly broken, it is seen that the outer lip is gently inclined from the carina with upward convexity. The apertural margin is most protruded near the transition from the outer to the basal wall. Then the margin becomes concave backward and more advanced near the suture than on the other side. The carina is shifted a little inward from the aperture through the last volution. The preservation of growth lines is poor.

Comparison.:—The spire of this species is not so much sunken as in *Lecanospira*, but not terraced as in typical *Helicotoma*. The type species of the latter genus is *Helicotoma planulata* SALTER with which this agrees well in the whorl section, apertural outline and other aspects. The umbilicus is, however, very narrow and deep in SALTER's and many other species of *Helicotoma*, while the early volutions are well exposed and not much sunken below the level of the ultimate whorl in this species. *Helicotoma umbilicata* ULRICH and SCOFIELD has also the umbilicus widely open, but in most other aspects it fits better with *Helicotoma* than *Burnesella*. In *Helicotoma* the spire is generally more rapidly expanding than in this species.

Euomphalus uniangulatus HALL which was referred to *Helicotoma* by SALTER and later authors, is similar to this species, but its spire coils more rapidly and the whorl section more rounded (CLOUD and BARNES, 1948) in comparison with this species. *Helicotoma* cfr. *uniangulata* by POULSEN from the Cape Clay formation of NW Greenland (1924) is more closely coiling than the typical *uniangulata* and may be allied to this species.

Burnesella lecanospiroides BRIDGES and CLOUD is the type species of *Burnesella* with which this species agrees in most characters, but the carina is submedian and inner slope thence steeper in that species. Accordingly the whorl section is subtriangular in that whereas it is subquadrate in this species.

Occurrence.:—Loc. 17.

Genus *Ozarkispira* WALCOTT, 1924, non ULRICH and BRIDGE, 1931

Ozarkispira leo WALCOTT

Plate I, figures 6a-c.

1924. *Ozarkispira leo* WALCOTT, *Smithsonian Misc. Coll. Vol. 57*, p. 37, fig. 6.

1941. *Ozarkispira leo* KNIGHT, *Geol. Soc. Am. Sp. Pap. No. 32*, p. 224, pl. 18, figs. 1a-c.

The spire of the best preserved specimen in this collection is more or less elliptical, due to secondary lateral compression. Otherwise it agrees with the precise description of this species given by KNIGHT.

The spire of the specimen is composed of 6 or more volutions. The diameter of the shell through the apertural end measures 11.5 mm. while another diameter rectangular to it is 12.2 mm. It is no better preserved to add any fresh observation to the specific description.

Occurrence.—Common at loc. 6. A specimen therefrom is well preserved. WALCOTT's holotype from the Mons in Alberta. According to KNIGHT *Raphistoma rotuliformis* MEEK (1870) from the Pogonip in Utah is probably identical with this species.

Ozarkispira sp. indet.

A fragmentary gastropod from loc. 7 is probaly congeneric with *O. leo* because it has a low spire and rhombic whorl section, but they are specifically different. The spire is expanding more rapidly in this than in that species, and accordingly the last whorl is proportionally broad in this species.

Occurrence.—Loc. 7.

Genus *Lytospira* KOKEN, 1896

Lytospira mediosulcata KOBAYASHI, new species.

Plate I, figures 7a-c.

Description.—Shell small, nearly planispiral and loosely coiling; upper wall slightly ascending through growth and the lower one descending in a greater degree; whorl section subcircular, a little broader than high; upper wall less convex than the others, but abruptly rounded on the two sides; median groove relatively broad

and shallow, provided with a blunt ridge on each side and running a little interior to the middle of the flattened upper wall; apical end of the type specimen abruptly rounded off, showing that the shell is septate in the adapical portion; growth lines sinuated on the median groove; surface smooth.

Comparison:—Due to the flattening of the upper plane the section of the whorl looks somewhat triangular, but the remaining part is well rounded. This species has the mesial groove on the top plane but no crest along the outer periphery of the upper wall as seen in *Ecculiomphalus* or *Ecciliopteris*. In *Euomphalus angelini* LINDSTRÖM (1884) which is the type of *Lytospira* the surface is lamellose and the upper wall angulated mesially. In this species there is a groove in place of the ridge, on the upper surface which is flattened in the vicinity of the groove, while the two sides of the angulation are sloping down in that species.

Liomphalus CHAPMAN (1916) is similar to *Lytospira* with which SHIMER and SHROCK synonymized it. *Liomphalus australis* CHAPMAN is its type having a smooth surface and a subovate to rhomboidal whorl section. The mesial groove with an obtuse ridge on each side is the most distinguishing characteristic of this genus.

Occurrence:—Loc. 6.

Class Cephalopoda

Order Nautiloidea

Family Robsonoceratidae ULRICH, FOERSTE, MILLER
and UNKELSBAY, 1944.

Genus *Robsonoceras* ULRICH and FOERSTE, 1936.

Robsonoceras sp.

Plate I, Figures 8a-c

Pragmacone orthoconic longicone, very slowly tapering; 6 camerae countable in the length of 7.2 mm.; cross section almost a circle, 5 mm. in diameter at the adapical end of the specimen; siphuncle marginal, also circular in cross section, about 1 mm. in diameter at the same point; septal sutures straight and nearly horizontal, but a little inclined toward the antisiphonal side.

When the shell and matrix are taken off, it is clearly seen that

the septal sutures run parallel to each other on the two sides of this narrow contact plane. Therefore it is understood that the siphuncle was directly in contact with the shell.

The siphonal margin of the conch was polished a little but no diaphragm was found in the siphuncle. The septa are not well preserved, but appear to be holchoanoidal. It is obvious in the longitudinal section that the septa are convex inward near the neck and more or less concave in the interval between the necks. The presence of diaphragms is the most significant characteristic of *Robsonoceras*, but their absence is not an objection of referring this specimen to the genus, because it is stated that the diaphragms are not present in the adoral portion of the siphuncle. This specimen agrees better with *Robsonoceras* than with *Ellesmereoceras*, because the conch is not compressed laterally and has no distinct lobe or saddle on the suture.

Occurrence.:—Loc. 3.

Phylum Arthropoda

Class Trilobita

In most text-books of palaeontology Trilobita have long been placed in Crustacea as one of their orders. Merit to STØRMER and some others, however, it was shown that Trilobita form an archaic group of Arthropoda independent from Crustacea.

The classification of Trilobita is still confused. As I have emphasized (1935), the major grouping based merely on the basis of cephalic sutures is not successful and one must rely on the combination of biocharacters. This conclusion was more and more ascertained in these years with new facts.

Through the ontogenetical study on *Redlichia chinensis* polymerism was readily distinguished from metamerism (KOBAYASHI and KATO, 1951). Namely, metamerism is the production of a new segment in the growth zone in the pygidium whereas polymerism is the migration of a segment from pygidium to thorax. In consequence the number of thoracic segments increases. Miomerism is the decrease in the number of thoracic segments which is seen in phylogenetic development. When polymerism ceases before the cessation of metamerism, the pygidium becomes larger and multisegmented. Therefore the

miomeric and macropygous trilobites are more advanced than the polymeric and micropygous ones. From this viewpoint agnostids are the most specialized trilobites, as I have discussed in great detail (1939).

The Agnostida are exclusively hypoparian and bisegmented in thorax, whereas the cephalic suture is either hypoparian or proparian and the thorax has 2 or 3 segments in the Eodiscida. Nevertheless these trilobites form a solid group in Trilobita (KOBAYASHI, 1944). JAEKEL's proposal of Miomera was adopted for this group by WHITEHOUSE, HUPÉ and some others.

Polymeric trilobites vary greatly. There were at least 3 major stocks already in the early Lower Cambrian period. They are Redlichida, Corynexochida and Conocoryphida.

Burlingia and *Schmalenseeia* with which the Norwoodidae and a few others may be combined, form a small Middle and Upper Cambrian group isolated from the preceding three orders for which I proposed "Burlingida" (1954).

The rise and fall of trilobite families which took place in the span of time from late Cambrian to early Ordovician were great and so sporadic that some of them are quite difficult to trace their lineages. One of such groups comprises the Dikelocephalidae, Asaphiscidae, Nileidae, Asaphidae, Bathyruridae and some others for which Dikelocephalida are reserved, because it is difficult to answer whether they were derived from the Corynexochida or Conocoryphida stock.

The major classification of the Trilobita, though still tentative, is adopted here as follows:

- A. Subclass Polymera JAEKEL
 - a. Order Redlichida RICHTER
 - b. Order Corynexochida KOBAYASHI
 - c. Order Dikelocephalida KOBAYASHI
 - d. Order Conocoryphida SWINNERTON
 - e. Order Burlingida KOBAYASHI
- B. Subclass Miomera JAEKEL
 - f. Order Eodiscida KOBAYASHI
 - g. Order Agnostida KOBAYASHI

Subclass *Polymera* JAECKEL, 1909.Order *Redlichida* RICHTER, 1932Family *Kainellidae* ULRICH and RESSER, 1930

The following species in EVANS' collection have already been described in my recent paper (1953):

Kainella flagricauda (WHITE) from First Mountain, 2 miles south of Sinclair Canyon mouth, British Columbia (Goodsir C₂).

Kainella stenorachis KOBAYASHI from North of the first stream from East, North of Brisco trail, British Columbia (Goodsir No. 37/7).

Lingukainella robusta KOBAYASHI from Whiskey trail, British Columbia (Goodsir No. 14/3).

Apatokephalus canadensis KOBAYASHI from North of first stream East, North of Brisco trail, British Columbia (B 7.).

Kainella stenorachis was founded on the pygidium the axis of which is as narrow as that of *Kainella meridionalis* KOBAYASHI. The fusion of the pleural ribs are, however, far more advanced. While the first rib is marked by a deep furrow in its whole length, the second one is united with the third except the distal end. There the rudimentary spine of the secondary rib still exists. The fusion is further advanced in *Kainella orientalis* RASETTI (1943) in which the posterior margin is entire between the first pair of the pleural ribs. As the preocular facial suture is transversal in the associated freek, *stenorachis* was taken for an aberrant form of *Kainella*, s. str. If the speciality corresponding to the pygidium is found in the cranidium, it may require at least its subgeneric distinction from *Kainella*, s. str.

Lingukainella can be distinguished from *Kainella* in the smaller axial lobe, the first and second pairs of well developed pleurae protruded into stout spines and the third pair united into a posterior tongue. In *L. robusta* the pleural furrows run into the spines and interpleural furrows pitted at the ends. Because of its resemblance with *Metopolichas celorrhin* (ANGELIN), I have provisionally placed the pygidium of *M.* (?) *martelli* in the Lichadidae. But now I think that it is probably congeneric with *Lingukainella robusta*.

Another which looks similar to *L. robusta* is the pygidium of *Dikelocephalus* (?) *corax* BILLINGS. The cranidium on which the species is founded is the type of *Bienvillia* by CLARK (1924). As questioned by BILLINGS himself (1865), it seems quite unlikely that the pygidium

goes with the cranidium, but it was found in the same mass of limestone in the Lévis conglomerate with the cranidium of *Bienvillia corax* which is thought Upper Cambrian (RASETTI, 1944). In the pygidium the pleurae become shorter from the first to the fourth and the fourth pair are fused along the axis where the median groove still remains. This is older and more primitive than *L. robusta*.

In cleaning specimens two more kainellids were found in the collection as follows:

Kainella kindlei KOBAYASHI, new species from loc. 2.

Apatokephalus canadensis KOBAYASHI from loc. 20.

Subfamily Kainellinae KOBAYASHI, 1953

Genus *Kainella* WALCOTT, 1924

Kainella kindlei KOBAYASHI, new species.

Plate II, figure 1.

Description.—Glabella large, convex, elevated above the cheeks, subquadrate, more or less expanded at the middle and surrounded by deep dorsal furrows; anterior lateral furrow obscure, while the posterior one is distinct, oblique, long and pronounced toward the axis; occipital furrow transversal; frontal limb narrow and depressed; frontal rim thick, convex, elevated above the limb; frontal furrow distinctly pitted; anterior facial suture transversal.

Comparison.—The type cranidium is 5 mm. long. In the glabellar aspect it resembles *Pseudokainella columbiana* KAY and HARRINGTON (1951), but the transversal anterior suture reveals its being a *Kainella*. Its glabella is broader than that of *K. billingsi* (WALCOTT), but longer than that of *K. orientalis* RASETTI (1943). The frontal limb is shorter in this than in the two kindred species. In fact the limb in the front of the glabella are about the same in length. The rim is remarkably convex. Its lateral narrowing in other *Kainellas* is imperceptible. Irregular radial ridges cannot be seen on this frontal limb. Though the cranidium before hand is imperfect, it can readily be distinguished from all of the known *Kainellas*.

Occurrence.—Loc. 2.

Subfamily Apatokephalinae KOBAYASHI, 1953

Genus *Apatokephalus* BRÖGGER, 1897*Apatokephalus canadensis* KOBAYASHI

Plate II, figure 2.

1953. *Apatokephalus canadensis* KOBAYASHI, *Japan. Jour. Geol. Geogr.* Vol. 23, p. 53, pl. 3, figs. 1-4.

The anterior part of this cranidium is broken off. Nevertheless it is typical of the species.

Occurrence.:—Locs. 20 and B7.

Family Pliomeridae RAYMOND, 1913

Protopliomerops is a cheiruroid, but referred to the Pliomeridae rather than the Cheiruridae, s. str., as done by HUPÉ (1953) because its alliance to *Pliomerops* and *Pseudomera* is greater than to true cheirurids.

Genus *Protopliomerops* KOBAYASHI, 1934*Protopliomerops subquadratus* KOBAYASHI, new species

Plate II, figures 3-4.

Description.:—Glabella one and a half times longer than broad, subquadrate, a little tapering backward and rounded in front, provided with three pairs of strong lateral furrows which are oblique to the axis and disconnected in the axial third; occipital furrow transversal; occipital ring shorter than the lateral lobe; dorsal furrow deep. Fixed cheek one and a half times broader than the glabella; its posterior rim somewhat thickened near the genal angle whence a short spine issues backward; rim itself bent forward and a little inward; eyes of medium size, lunate, a little anterior to the second lateral lobe of the glabella; fixed cheek at the eye half as wide as the glabella; ocular ridge extends from the vicinity of the first lateral furrow. Facial suture extends transversally from the posterior end of the eye and cuts the lateral margin of the cheek.

Pygidium subquadrate; axial lobe nearly a third as wide as the frontal margin of the pygidium, conical, regularly convex, elevated above pleural lobes, composed of 5 rings and a terminal lobe; dorsal

and ring furrows strong; terminal lobe depressed below the level of the rings, triangular, pointed back, bisected half way by an axial furrow which extends back from the fifth ring furrow; pleural lobe only a little convex, composed of 5 pleurae which are separated by deep grooves and each protruded back into a spine; the first pleura divided into a narrow anterior and a broad posterior band by a transverse furrow which extends laterally in the same line with the furrow which divides the articulating half-ring from the first ring; posterior band abruptly turns back and prolonged into a spine with weak convexity on the lateral side, a little further beyond the posterior end of the axial lobe.

Observation.:—The description is based on a cranidium and pygidium in separate slabs from the same locality. This pygidium belongs to the same kind with another pygidium found on the same slab with the cranidium. The cranidium is 27 mm. broad. It is deformed to some degrees as can be perceived by a comparison between the two cheeks. The posterior margin is nearly straight on the left but undulated on the right side. The glabella is 7 mm. wide and 11 mm. long. The test appears to be pitted at least on the cheek. Covered by tenacious matrix, its frontal rim is invisible. The pygidium is about 11 mm. broad, its axial lobe 3.3 mm. broad and 6.5 mm. long.

Comparison.:—*Protopliomerops primigenus* (ANGELIN) and *P. deferrariisi* HARRINGTON (1939) are two close allies to this species. The relatively posterior position of the eye on the broad cheek is a significant characteristic found common among them. While *primigenus* has no genal spine (MOBERG and SEGERBERG, 1906, pl. 7, figs. 13a-b), *deferrariisi* has it. The axial lobe of the pygidium is, however, much broader in *deferrariisi* than in this species. Not only in the relative size of the axis to the pygidium but also in the central pit on the terminal axial lobe (ANGELIN, 1878, pl. 41, fig. 15) this pygidium fits nicely with that of *primigenus*. The outline of the pygidium is, however, different between the two.

The pygidium of *Pliomerops canadensis* (BILLINGS) (1865, fig. 278) looks very similar to this pygidium, but the axis is a little broader and the triangular terminal lobe simple in BILLINGS. The cephalon of *Pliomerops canadensis* is quite different from that of *Protopliomerops* in the shorter subpentagonal glabella with the first lateral furrow cutting into the glabella from the frontal furrow and the

lack of the genal spine.

Amphion salteri BILLINGS for which BRADLEY (1925) proposed *Strotactinus* has also a similar pygidium. According to him, it is a common member in the Beekmantown limestone at Phillipsburg, Quebec. The pygidium of *salteri* which BRADLEY illustrated appears to have 6 pleural segments whereas there are only 5 in BILLINGS' type. The eyes are located at about the mid-length of the cranium. BRADLEY noted the similarity of *salteri* to *Ceraurinus*.

Occurrence:—Loc. 21.

Protopliomerops radiatus KOBAYASHI, new species

Plate II figure 5a-b, 6.

The type cranium is 28.5 mm. wide. Glabella 8 mm. long and 11 mm. broad, strongly convex, quadrate but its antero-lateral corners are rounded; three pairs of lateral furrows oblique to the axis and deep; posterior furrow strongly pitted at the inner end; occipital furrow strong and undulate; occipital ring thickened in the middle; dorsal furrow quite pronounced; eyes opposed to each other at the second lateral furrows; fixed cheek half as wide as the glabella at the eyes, well developed postero-laterally and remarkably slant outward from the eye; genal spine absent; anterior rim upturned; posterior facial suture transversal.

The surface of the cheek is distinctly pitted. Some diagonal ridges are clearly seen on the first left lobe of the glabella, but they are not preserved in the remainder of the glabella.

The cranium has many aspects in common with the preceding, although they are evidently different specifically. A pygidium procured from the same locality with the cranium is also closely related to that of *P. subquadratus*.

The axis of the pygidium is composed of 5 rings and a terminal triangular lobe which the last bears the same aspect as those of *P. primigenus* and *P. subquadratus*. The five pairs of pleurae are more widely divergent in this than in these two allies but less so than in *P. supercliosa* ROSS.

In this aspect this pygidium may be compared with *Protopliomerops firmimarginis* HINTZE, (1952, pl. 22, fig. 1a). The axial lobe is a little broader in front and tapers more abruptly in *firmimarginis* and *supercliosa* than in this species.

Amphion barrandei BILLINGS for which HOLLADAY (1942) erected *Pseudomera* has a pygidium (BILLINGS, fig. 278) very similar to this, although the axis is more slender than that of *Protopliomerops radiatus*. The cephalon of *Pseudomera barrandei* agrees with *Pliomerops* much better than with *Protopliomerops*.

Finally it is noted that the pleural ridges in the pygidium of *P. radiatus* are rounded on the top but the spines mesially grooved. The test of the pygidium is calcified and appears smooth.

Occurrence:—Loc. 13.

Protopliomerops longispinus KOBAYASHI, new species

Plate II, figures 7.

This is represented by a small pygidium, 14 mm in breadth. The axial lobe is a third as broad as the pygidium, but tapers quickly backward. It is composed of 5 rings and a triangular terminal lobe. The anterior margin of the pygidium is broadly rounded in form of a semicircle. The breadth of the pygidium attains at the maximum at a point shortly behind the rear end of the axial lobe. Pleural lobes are divided into 5 ridges by narrow but distinct furrows, each of which is prolonged back into a long spine. The anterior spines are longer than the posterior ones. They appear to terminate nearly on the same transverse line.

This is similar to the pygidium of *Protopliomerops supercliosa* ROSS (1951) in the young stage, but the anterior margin is more rounded, the spines are longer and the axial lobe is more breviconic. Because there is no linking form between this and *P. subquadratus*, they are specifically distinguished.

Occurrence:—Loc. 13.

Genus *Tesselacauda* ROSS, 1951

Tesselacauda flabella KOBAYASHI, new species

Plate II, figures 8a-b.

Description:—Axial lobe broad, breviconic, rounded at a fourth the length from the posterior margin, scarcely elevated from the gentle general convexity of the pygidium and composed of 4 rings and a small triangular terminal lobe; anterior margin of the pygidium broadly arched and its pleural part nearly diagonal; 4 pleurae

countable on each side; interpleural furrows somewhat divergent and accordingly the pleurae are broadened distally; pleural furrows short but distinct in the anterior pleurae; each pleura truncated at the end but its junction with a neighbouring pleura is incised; such an incision cuts into the side-lobe as far as a circular pit where the interpleural furrow terminates. Test smooth.

Comparison:—The above observation is made on the exfoliated surface except a very periphery where the test still remains. The axial lobe inclusive the articulating half-ring is 8.1 mm. long and 7 mm. broad. The pygidium may be about 11.5 mm. long and 16.5 mm. broad, if complete. The pygidium is longer than *T. depressa* ROSS (1951), but reveals good agreement with the holotype pygidium of that species in essential features. The entire margins of the pygidia in these species are, however, quite unusual for the cheiruroid, s.l.

Occurrence:—Loc. 2.

Order Corynexochida KOBAYASHI, 1935

Family Telephidae ANGELIN, 1954

The family was well founded by HADDING's revision (1913). Subsequently when RAYMOND (1925) combined *Telephus* with *Cyclopyge* CORDA and *Symphysops* RAYMOND in a family, he proposed Cyclopygidae for it, owing to the invalidity of *Aeglina* ANGELIN, 1947 and accordingly of Aeglinidae PICTET, 1854. From this viewpoint the Cyclopygidae is a synonym of the Telephidae but the two families are independent, as generally conceived at present.

ULRICH (1929) referred *Glaphurus* RAYMOND and *Glaphurina* ULRICH to the Telephidae, but the two genera look more allied to the Odonotopleuridae as suggested by RAYMOND. ULRICH noted the alliance of *Telephus* to *Chariocephalus* and *Irvingella*.

The latter two were later combined with other genera in the Komaspidae by KOBAYASHI (1953). Lately Telephacea was proposed by STUBBLEFIELD (1950) to include the Telephidae and the Komaspidae. The latter family divided into the Bathynotinae (Lower and Middle Cambrian) and Komaspinae (Middle Cambrian and Lower Ordovician) by KOBAYASHI (1954). The Komaspinae must be ancestral to the Telephidae, but there are some links still unnamed between them,

Distribution:—Same as *Telephus*.

Genus *Telephus* BARRANDE, 1852.

In ULRICH's monograph (1929) 27 species and 2 varieties are distinguished in this genus. They were all represented by dismembered carapaces, but 9 segments are countable in the thorax of FISCHER's complete carapace of *Telephus spiniferus* ULRICH (1946).

With reference to glabellar outline and course of eye-bands European 10 species may be classified into 4 or 5 groups.

1) *Fractus* and *reedi* having a trapezoidal glabella and laterally angulated eye-bands.

2) *Salteri* having a glabella dilating in the anterior and eye-bands developed postero-laterally.

These are two European off-shoots which were issued from the trunk composed of the following groups:

3) *Mobergi* group having a trapezoidal glabella and antero-laterally developed eye-bands.

4) *Granulatus* group having an oval or elliptical glabella with well rounded eye-bands.

5) Intermediate group between these two (3 and 4).

As the result of ULRICH's rigorous discrimination, American forms attained almost twice the number of European ones, but it does not literally mean that morphic diversity is greater in America than in Europe, because the first and second groups are unrepresented.

It is interesting to see two hollow spines issuing from the anterior part of the glabella in *granulatus* ANGELIN by HADDING and *bicornis* ULRICH which are approximate contemporaries on the two sides of the Atlantic. In eastern North America the *mobergi-wegelini* group is represented by *bipunctatus*, *impunctatus*, *prattensis*, *tellicoensis*, *buttsi*, *troedssoni*, *transversus* and *hircinus*; *granulatus* group by *americanus*, *mysticensis*, *mysticensis similator*, *bilunatus* and *bicornis*; and the remainder belongs probably to the intermediate group.

Distribution:—Chanzyan or Llandelian and later. From the southern Appalachians to Scandinavia through Quebec, Newfoundland and Scotts-Irish area and extending into Bohemia. The present find in western Canada is the first in the rest of the world.

Telephus pacificus KOBAYASHI, new species

Plate II, figures 9a-b, 10.

Description:—Glabella triangularly ovate, strongly convex, pro-

vided with a pair of strong pits in the posterior part; occipital ring clearly defined anteriorly by a profound furrow, and thickened toward the middle it is pointed back; occipital groove remarkably bent forward in the middle part, but bent back on the two sides; dorsal furrow deep; frontal rim narrow, wire-like, gently arcuate and separated from the glabella by a narrow but deep groove; two short spines issue near its lateral ends; starting from this point, the eye-band, twice thicker than the rim, extending postero-laterally but turning inward and backward before passing its half way; cheek bordered by the band broad, moderately convex and inclined laterally; posterior limb of the cheek very small; surface apparently smooth.

Observation.:—The holotype cranidium is 3 mm. long. The paratype is an external mould of a larger cranidium the glabella of which is 4 mm. in breadth and 5.5 mm. in length where the occipital ring occupies 1.5 mm. of the length.

The glabellar pits are not so strongly impressed internally.

Comparison.:—In the presence of two strong pits this belongs evidently to the group of *T. mobergi* HADDING, which occurs in Sweden in the Llandailian *Ogygiocaris* shale. The group comprises several American species, namely *troedssoni* RAYMOND, *bipunctatus* ULRICH, *impunctatus* ULRICH, *prattensis* ULRICH, *tellicoensis* ULRICH, *herecinus* ULRICH and *buttsi* ULRICH which are intimately related to one another and occur all in the upper Chazy in the Appalachians.

This species well agrees with *mobergi*, *bipunctatus* and *buttsi*, but the eye-bands are not so distinctly geniculate and there is no trace of the nuchal spine.

Occurrence.:—Loc. 10.

Family Leiestegiidae BRADLEY, 1925.

Subfamily Leiestegiinae KOBAYASHI, 1935

Genus *Leiestegium* RAYMOND, 1913

Subgenus *Evansaspis* KOBAYASHI, new subgenus

Diagnosis.:—*Leiestegium* with a pair of spines issuing from the lateral border of the pygidium.

Type species.:—*Leiestegium (Evansaspis) glabrum* KOBAYASHI, new species.

Remark.:—As listed by HINTZE (1952), there are 9 species of

Leiostegium having entire margins on their pygidia. The tenth species is *Leiostegium formosa* HINTZE which has a pair of lateral spines on the pygidium. *Perischodory* RAYMOND (1937) which is known only of the pygidium of the monotypic *Perischodory grandgei* RAYMOND (Pl. IX, fig. 11) has also a pair of spines which, however, spring out from the lateral ends of the frontal margin.

Prochuangia KOBAYASHI (1935) also has a pair of spines on the pygidium. It has, however, no marginal border and a pleural ridge is protruded into a spine without any interruption.

The pygidium of *Chosenia* (KOBAYASHI, 1934) is, like the precedings, provided with a pair of lateral spines, but it can easily be distinguished from the pygidium of *Evansaspis* by its subpentagonal outline and distinctness of pleural ribs and furrows. The spine is the prologation of the first pleural rib.

Although the presence or absence of such spines is often taken for a generic or even higher distinctoin, *Evansaspis* is recongnized here as a subgenus of *Leiostegium* because it agrees well with *Leiostegium*, s. str. in the cranidium.

It is probable that *Crepicephalus ceratopygoides* RAYMOND (1925) from the Lower Ordovician in the east of Harrogate, B. C. belongs to *Evansaspis*. However, I hesitate this reference because it is stated that "the lateral spines are not mere extensions of the margin, but are prolongations of the convex portion of each pleural lobe." Furthermore its illustration does not show any well defined marginal rim. Specifically the pygidium is distinct from *glabrum* as well as *formosa* in outline, longer axial lobe and the more anterior position of the lateral spines.

Distribution:—*Leiostegium*, s. str. is widely distributed in Americas. The one from Cajas, 15 miles west of Hambacca, Argentina, which I listed elsewhere (1936, 37), belongs to *Leiostegium douglasi* HARRINGTON, insofar as can be judged from its pygidia. The known distribution of *Evansaspis* is, on the other hand, restricted to western North America.

Leiostegium (Evansaspis) glabrum KOBAYASHI, new species

Plate II, figures 11–17.

Description:—Glabella fairly convex, long, subquadrate, somewhat contracted in the mid-length and smooth, but provided with a

strong occipital furrow; dorsal furrow deep and pitted at the frontal end; fixed cheek narrow; eyes large, provided with a deep furrow on the inner side; eye ridge absent; fixed cheeks remarkably depressed in front of the eyes; frontal rim narrows in front of the glabella; anterior facial suture nearly parallel to each other.

Pygidium moderately convex, somewhat pentagonal; axial lobe narrow, distinctly elevated above the pleural lobes and rounded at the rear; four rings in its anterior half clearly separated from one another by transverse furrows, but the segmentation becomes obscure backward; pleural lobe broad and unfurrowed except the first pleural furrow; anterior pleural ridge continues to the marginal border at the lateral end where the margin of the pygidium is more or less oblique and rounded; marginal border convex, delimited by a deep furrow on its inner side; a pair of spines which divide the posterior and lateral margins into three parts of subequal length, issue postero-laterally.

Observation.:—A hypostoma from loc. 8 is long, subpentagonal, but alated at the lateral ends of the gently arcuate frontal margin; central body large and subelliptical, but subangulated at the rear end as does the marginal rim; intramarginal furrow deepened inside of the bent of the rim toward the wing.

An imperfect free cheek from loc. 2 which is thought to belong to this species has a genal spine.

Comparison.:—This species is quite similar to *Leiostegium formosa* HINTZE, if their pygidia are compared. The imperfect cranidium of the latter, however, shows that the glabella appears to be a little narrower and strongly contracted. Its eyes are less curved than those of this species. The most important distinction between the two species lies in the texture of the carapace which is pustulose in *formosa* but smooth in this species.

Occurrence.:—Locs. 2, 8, 12 and 25. There is neither pustulose *formosa* nor any species of *Leiostegium*, s. str. in the collection before hand.

Order Dikelocephalida KOBAYASHI, 1935

Family Asaphiscidae RAYMOND, 1924

Genus *Hyperbolochilus* ROSS, 1951

Hyperbolochilus expansus KOBAYASHI, new species

Plate III, figure 1.

Description.:—Cranidium moderately convex, doming toward its

center; its length exclusive of the neck ring equal to the breadth of the glabella plus a fixed cheek; glabella clearly outlined by a narrow dorsal furrow, ovate, slightly elevated above the general convexity of the cranidium, nearly half as wide as the cranidium; its breadth equal to the length of the glabella exclusive of the neck ring; no lateral furrows; occipital furrow as strong as the dorsal one and more or less undulate; occipital ring sublenticular; eyes medium in size, close-set to the middle of the glabella; no ocular ridge; fixed cheek very narrow at the eye, but its posterior limb is well developed laterally; preglabellar field remarkably expanded and inclined distally with weak convexity; frontal border depressed, separated from the frontal limb by a shallow furrow and more or less arched toward the axis; anterior facial suture running diagonally from the eye but incurved on the marginal border; posterior suture subtransversal, but turns backward near the end. Test smooth.

Comparison.:—This species agrees with *Hyperbolochilus margin-auctum* ROSS (1951) in major aspects, but the glabella and preglabellar field are broader. The eyes are located more posteriorly and accordingly the fixed cheeks behind them more transversal. The facial suture does not cut the frontal border so far inward as in that species.

As ROSS' species occurs in the F zone of the Garden City formation, it is much younger than *Hyperbolochilus expansus*. ROSS illustrated various kinds of hypostomata and pygidia found in association with his species. Some of the hypostomata (ex. fig. 25, pl. 19, in ROSS, 1951) could be of the Asaphiscidae. Those pygidia are, however, all very broad and the marginal border is not well developed in them. They are quite distinct from either the Asaphiscidae or the Bathyuridae.

In *Bathyurellus glensaulensis* REED (1910) from Glensauale distinct, Ireland, the glabella is smaller than in typical *Bathyurellus*, eyes also much smaller and closely set to the glabella and the marginal border is very narrow. REED's cranidium in figs. 2a-b has the strongly rounded anterior outline probably due to lateral compression which yielded the axial angulation on the glabella. This species is much larger than and its neck ring not thickened mesially as in *Hyperbolochilus*, but it is a question with which it agrees better, *Hyperbolochilus* or *Bathyurellus*.

Acrohybus argutus RAYMOND (1937) from the Rockledge conglom-

merate which he considered a member of the Cedariidae looks very similar and possibly related to this species, but they are generically distinct, because the glabella is more triangular, the occipital furrow obscure, the frontal brim flattened and the rim ill-defined in that species. The incurving of the facial suture on the frontal border as seen in *Hyperbolochilus* is not shown in its illustration.

In the incurving of the suture and the presence of the clear-cut neck ring *Hyperbolochilus* fits with *Homodictya* nicely. Its type species is *H. imitatrix* RAYMOND (1937) which was lately studied by RESETTI (1952) and SHAW (1952) with fresh materials. There are of course some differences among the individuals described by the three authors, but all of them have the eyes more anteriorly, if compared with *Hyperbolochilus*. Accordingly the posterior limb of the fixed cheek is larger. Furthermore the anterior outline of the cranidium is more rounded. The frontal border is upturned and no furrow present on its inner side. Thus there are some distinctions, but nevertheless the two genera are intimately related.

RASETTI and SHAW agree in the reference of the pygidium resembling that of *Blountia* to *Homodictya imitatrix*. While RAYMOND placed *Homodictya* in the Tsinanidae, SHAW took it for a subgenus of *Blountia* in the Asaphiscidae. As discussed above, *Acrohybus* is also possibly a member of the same family. *Hyperbolochilus* may be a relic genus of the Asaphiscidae in the early Ordovician period. Another possibility of its family reference is, however, found in the Bathyruridae.

Occurrence:—Loc. 2.

Family Nileidae ANGELIN, 1854

RAYMOND (1922) suggested *Symphysurus* for certain trilobites from western North America, but they are now referred to *Symphysurina*. "*Symphysurus? goldfussi*" WALCOTT (1884) is the type species of *Pseudolenoides* HINTZE (1952) which bears similarities with the Damesellidae in several aspects.

The specimens described below are too incomplete to confirm their generic or family reference.

Gen. et. sp. indet.

Plate V, figures 20-21.

A fragmentary cranidium is largely occupied by the glabella which is remarkably expanded in the anterior. Eyes are broken off but surmised to have been located close to and a little posterior to the middle of the glabella. Neither occipital nor lateral furrows are present. Dorsal furrows are, however, fairly strong behind the eyes and pitted at the place of the occipital furrows. A median tubercle is present between these pits. The cranidium is not drooping as commonly seen in *Nileus* and *Symphysurus*, but gently convex toward its center.

An associated pygidium is somewhat similar to *Asaphellus* (?) *canadensis*, but the axial lobe is less prominent. The lobe is narrow for the Nileidae and longer than in *Nileus* and *Symphysurus*. The marginal border is fairly well defined as in British genera of the Nileidae. This looks more likely a member of the Nileidae than of the Symphysurinae.

A hypostoma on the same slab is long, strongly convex and ovate, narrowing posteriorly. If it is combined with these parts of the dorsal shield, it is very difficult to say the family in which such a trilobite is included.

Occurrence.:—Loc. 9.

Family Asaphidae BURMEISTER, 1843

As the result of recent studies on silicified materials by ROSS and HINTZE the morphology of Canadian asaphid genera was greatly improved. *Bellefontia*, *Isoteloides*, *Kirkella*, *Lachnostoma*, *Parabellefontia*, *Symphysurina*, *Trigonocerca*, *Trigonocercella* and *Xonostegium* are all well characterized by combination of characters of dorsal shields and hypostomata. *Symphysurina* and its allies are grouped here in a new subfamily, Symphysurininae. In view of these genera I do not hesitate to say that endemic colour is quite distinct in the trilobite fauna of western North America.

As some old members of these genera used to be called *Asaphus* or *Megalaspis*, there are certain species which bear similarities to Atlantic asaphids. Some others are still placed in *Niobe*, *Asaphellus* or *Asaphelina* provisionally. Insofar as the thorax and pygidium are

concerned, *Asaphelina* from the Garden City formation is almost inseparable from *Asaphelina* from South France. Some crandia of *Asaphellus* (?) and also *Macropyge* (?) on the other hand appear to me to belong probably to *Kobayashia* which is an endemic genus founded by HARRINGTON (1938) on *Xenostegium taurus* from the Mons.

The high endemism in the well known asaphids casts a doubt how many of the little known asaphids from the Canadian in western North America can safely be referred to Atlantic genera.

Because the Asaphidae have been far splitted, it is almost impossible to make any exact identification of fragmentary carapaces ex. Asaphids indt. a, b, c. Some broad pygidia with concave borders may belong to *Bellefontia*. Some others with caudal spines look similar to *Kayseraspis*. There is an interesting asaphid form represented by pygidia from locs. 4 and 14 which are referred to *Protopresbynileus* very tentatively. They have post-axial pits on their doublure, but no concave border is present.

Subfamily Symphysurininae KOBAYASHI, new subfamily

This includes asaphids resembling *Symphysurus* in the dorsal view. The cranidium lacks the frontal rim; pygidium semi-circular or subtriangular in outline and lacks any well defined border. The glabella is broad, unfurrowed and separated from the cheeks by dorsal furrows which are fairly distinct in the posterior part; their posterior limb small and triangular. A median tubercle is generally present near the center of the glabella. The anterior facial sutures are subparallel or a little divergent or convergent. The doublures of the free cheeks bear several pits on the lateral sides. They meet along the median suture.

The Nileidae, on the contrary, lack the median suture. ULRICH mentioned 9 segments in the thorax of *Symphysurina*, but in *S. brevispicata* HINTZE it really consists of 8 segments and the hypostoma is attached with the doublure without rostrum.

According to ULRICH "The associated hypostoma is broadly alate, with a deep pit at the middle of the anterior edge making this part appear bilobed, median portion strongly swollen; posterior margin rounded, with two concentric, partly interrupted ridges. The marginal ridge dies out forward on the posterior part of the anterior wing."

Two hypostomata found together with *S. elegans* POULSEN (1937)

are long, subquadrate and quite different from the one of *S. minima* SHAW which in turn agrees well with ULRICH's diagnosis. In the outline with large anterior wings it is similar to certain hypostoma of the Illaenidae, but quite different from those of either the other Asaphidae or the Nileidae.

ULRICH concluded that *Illaenurus*, *Symphysurina* and *Hemigyraspis* represent three stages in the evolution from unknown Illaenurinae, but the posterior eyes and wide transversal suture behind them are specialities of *Illaenurus* quite distinct from the two other genera.

With the emphasis of the median suture and eight segments in thorax, it is reasonable to place *Symphysurina* in the Asaphidae as done by REED (1930). RAYMOND (1937) brought the genus together with his two new genera into the Ogygiocarinae probably because of the entire posterior outline of the hypostoma. But I think it better to erect a new subfamily for *Symphysurina* and its allies as suggested by POULSEN (1937), because they are *Symphysurus* like asaphids quite different from the Ogygiocarinae or the Asaphinae.

The older members of the subfamily were all referred to *Symphysurus* by BRÖGGER (1896) or RAYMOND (1910, 22) and they are

Asaphus illaenoides BILLINGS, 1860

Illaenus eurekaensis WALCOTT, 1884

Ampyx (?) sp. WALCOTT, 1884

Asaphus convexus CLELAND, 1900

Bathyrurus (?) sp. CLELAND, 1900

Illaenurus columbiana WELLER, 1902.

Bathyrurus (?) *levis* CLELAND, 1903.

Tsinania cleora WALCOTT, 1914.

Tsinania elongata WALCOTT, 1914

Since *Symphysurina* had been established by ULRICH (in WALCOTT, 1924, 25), RAYMOND erected *Symphysurinella* and *Symphysuroides*. The last one in particular is so similar to *Symphysurus* that the two are difficult to be distinguished in the dorsal view. Therefore I consider that the Symphysurininae reveal a branch of the Asaphidae which lies between the Ogygiocarinae and the Nileidae.

Putting aside several indeterminable forms, there are some 25 species in this subfamily which require a thorough revision. The convexity of the cephalon varies among them to a great extent. The cranidium is broad in the *woosteri* type but narrow in the *spicata* type. Genal spines are present in many species but absent in

eurekensis, *cleora* and some others. The anterior facial sutures are parallel in some but in others divergent or convergent to some extent. The frontal margin of the cranium is generally straight or slightly arcuate, but well rounded in *columbiana*. These criteria are, however, not very practical for grouping because there are gradations. The median tubercle is located at about the center of the cranium in most species.

RAYMOND (1937) distinguished his two genera from *Symphysurina* in the following manner:—

Symphysurinella:—Similar to *Symphysurina* but with unfurrowed triangular pygidium with a caudal spine issuing from the posterior border, instead of the axial lobe.

Symphysuroides:—Similar to *Symphysurina* but without caudal spine on the pygidium.

SHAW (1952) noted that the separation of *Symphysuroides* from *Symphysurina* on the basis of pygidia alone is of no more than sub-generic value. HINTZE (1952) on the other hand synonymized RAYMOND's two genera with *Symphysurina*.

Symphysurina woosteri is indeed remarkably similar to *S. brevispicata* except the presence or absence of the caudal spine. Such a spine or telson serves, however, for a distinction which is frequently applied to generic distinction among trilobites. Its importance may be recognized from the fact that all of the Arctic forms of the Symphysurinae are spineless. Therefore as a step toward the natural grouping *Symphysuroides* is accepted here as a subgenus of *Symphysurina*.

I am not sure of the validity of *Symphysurinella*. According to RAYMOND *Symphysurina* (?) *entella* of which the pygidium in fig. 22 (WALCOTT, 1925) is his lectotype, is a species similar to *Symphysurinella corlissensis* (Pl. IX, fig. 3), but as ROSS (1951) referred *entella* to *Trigonocerca*, its cephalic aspect agrees better with *Trigonocerca* than *Symphysurina*. It, however, disagrees with *Trigonocerca* in the lack of any distinct border either on the cephalon or on the pygidium.

Symphysurina globocapitella HINTZE is an abnormal form having unusually long eyes located far posteriorly. Combined with the strong convexity of the cephalon, diminution of the posterior limb of the fixed cheek, and broadening of the pygidium the characteristic may be more than specific value.

Finally the resemblance of *Symphysurina* with the Tsinanidae

is probably superficial. The hypostoma of *Tsinania canens* is quite different from that of *S. minima*. *T. humilis* has a pair of rudimentary lateral spines on its pygidium (KOBAYASHI, 1952). In *Dictyella* the marginal border is fairly well defined and a caudal spine issues from it. As noted elsewhere (KOBAYASHI, 1933), the pygidium of *Iliaenurus ceres* by MANSUY, i.e. *Dictyella* (?) *mansuyi* KOBAYASHI from the *Prosaugia* zone of Lungco, Indochina, has the pygidium similar to that of *Symphysurina*, but the associated cranidia are entirely different from that genus.

Distribution :—Lower Canadian; North America and Arctic province.

Genus *Symphysurina* ULRICH, 1924

Symphysurina woosteri ULRICH is the type species of this genus. The breadth and convexity of the axial lobe are quite different between the two type pygidia of the species (figs. 9–11), notwithstanding that they are not much different in size. The test is said to be either smooth or very minutely punctate. Therefore *woosteri* could be a composite species. POWELL's pygidia from the Oneota dolomite in southeastern Minnesota (1935) which are broad and spineless may not belong to *woosteri*.

S. spicata ULRICH, *S. eugenia* WALCOTT and *S. corlissensis* RAYMOND are additional members. LOCHMAN and DUNCAN (1950) synonymized the second with the first, but considerable difference in the convexity between the two cranidia can hardly be overlooked.

An artificial key to the specific identification of *Symphysurina* s. str. including *Symphysurinella* is given below.

Spine issuing from the prominent axial lobe on the pygidium.

Cranidium and glabella broad.

Pygidium long*S. woosteri*

Pygidium short and triangular.....*S. uncaspicata*

Pygidium short and semicircular.....*S. tatondakensis*

Cranidium and glabella narrow; pygidium triangular.

Glabella gently convex.....*S. spicata*

Glabella strongly convex*S. eugenia*

Spine issuing from the rear of the pygidium behind the end of the axial lobe*S. corlissensis*

On the basis of the above distinction *Symphysurina* (*Symphy-*

surina) *tatondakensis* (nov) is proposed for *Symphysurina* aff. *woosteri* by KOBAYASHI (1936).

Illaenurus eurekaensis WALCOTT, *Tsinania elongata* WALCOTT, *S. parva* RAYMOND *S. globosa* RAYMOND and *S. uncaespicata* HINTZE belong to this genus, but their subgeneric reference is indeterminate owing to the ignorance of their pygidia.

Distribution:—Lower Canadian; North America.

Subgenus *Symphysurina* KOBAYASHI, new subgenus

Symphysurina (*Symphysurina*) *spicata* ULRICH

Plate III, figures 8-9.

1884. *Ampyx*? WALCOTT, *Monogr. U.S. Geol. Surv. Vol. 8*, pl. 12, figs. 19.
 1925. *Symphysurina spicata* ULRICH in WALCOTT, *Smithson. Misc. Coll. Vol. 75*, p. 113, pl. 21, figs. 12-18.
 1950. *Symphysurina spicata* LOCHMAN and DUNCAN, *Jour. Pal. Vol. 29*, p. 352, pl. 52, figs. 8-12.

Compared to *woosteri*, the cranium is longer and the pygidium shorter in *spicata* and *eugenia*. According to LOCHMAN and DUNCAN the latter two are synonymous, but WALCOTT has shown that the convexity of the cranium is quite different between the two, and noted that the genal and caudal spines are not so developed in *eugenia* as in *spicata*.

There are a few cranidia and a pygidium from loc. 18 which are identifiable with *spicata*. The outline of the pygidium is also similar to that of *uncaespicata*, but the spine is extended horizontally and not so long as in *S. uncaespicata*.

Occurrence:—Loc. 18; Goodwine formation in Eureka district, Nevada,

Symphysurina (*Symphysurina*) *spicata* var. *eugenia* WALCOTT

Plate III, Figure 22.

1925. *Symphysurina eugenia* WALCOTT, *Smithson. Misc. Coll. Vol. 75*, No. 3, p. 113, pl. 21, figs. 21, 25-29, 32.

The specimens from loc. 24 agree better with *eugenia* than with *spicata*. The cranidia are more convex, although not geniculate as in typical *eugenia*. A small cheek appears to lack a spine at the genal angle. A pygidium has a little longer outline and the caudal spine shorter, if compared with *spicata*. This form is intermediate.

between *spicata* and *eugenia* but evidently closer to the latter. *S. eugenia* is probably not distinct species, but a variety of *spicata*.

Occurrence:—Loc. 24; Mons formation in Alberta.

Symphysurina (*Symphysurina*) cfr. *corlissensis* (RAYMOND)

Plate VII, figures 22a–b.

1937. cfr. *Symphysurinella corlissensis* RAYMOND, *Bull. Geol. Soc. Am.* Vol. 48, p. 1116, pl. 4, figs. 21–22.

The third form of this genus is different from the precedings primarily in the poorly outlined axial lobe. This pygidium agrees best with *corlissensis*. The lobe is elevated above the pleural lobes and slopes down abruptly near the posterior margin. Then it extends into a caudal spine, instead of being rounded off before the projection of the spine as it is the case of *corlissensis*.

In view of such an intermediate form I think it difficult to draw a sharp boundary between *Symphysurina* and *Symphysurinella*.

Occurrence:- Loc. 24.

Subgenus *Symphysuroides* RAYMOND, 1937

The genus was founded by RAYMOND on *Symphysuroides latus* RAYMOND of which only the pygidium and free cheek are known. A good concept of the dorsal shield is, however, available from *Symphysurina uncaspicata* HINTZE. A genal spine is present on the cheek in this as well as *Symphysurina* (*Symphysuroides*) *minima* SHAW of which the hypostoma is known. The genal spine is commonly present in *Symphysurina*, s. str. but less so in *Symphysuroides*. The spineless forms are

Asaphus illaenoides BILLINGS

Asaphus convexus CLELAND

Bathyurus (?) *levis* CLELAND

Illaeonurus colombiana WELLER

Tsinania cleora WALCOTT

RAYMOND considered CLELAND'S and WELLER'S species are all identical but the cranidium of *columbiana* is much broader than the two others which are similar to each other.

Putting aside *S. (?) simulans* POULSEN, it is noteworthy that the

three species from Northwest Greenland (*inermis*, *porifera* and *tumida*) have tests pitted internally and in the two (*robusta* and *elegans*) from East Greenland the surface of the test is pitted.

Distribution:—Lower Canadian; North America and Greenland.

Symphysurina (Symphysuroides) elegans POULSEN

Plate III, figures 19–21.

1937. *Symphysurina elegans* POULSEN, *Medd. om. Grønland*, Bd. 119, Nr. 3, p. 37, Pl. 2, figs. 11–18.

In the outline and convexity of the cranidium *woosteri* ULRICH *elegans* POULSEN and *brevispicata* HINTZE are quite similar, but the first species is different from the two latters in the presence of a caudal spine on the pygidium. POULSEN states that “the surface of the test (of *elegans*) is marked by numerous microscopic pits.”

Two cranidia and a pygidium from loc. 22 and a pygidium from loc. 19 have punctate tests. These cranidia are a little less convex than POULSEN's in fig. 12. The pygidium from loc. 22 has the angulated posterior outline; the axial lobe not very prominent; pleural segmentation practically obsolete; side lobes slope abruptly near the postero-lateral margin, while they are said to be gently and uniformly inclined in POULSEN's. Thus there are minor differences. Nevertheless the form from loc. 22 is, if not identifiable, most closely related to *elegans*.

Occurrence:—Loc. 22; Cass Fjord formation in East Greenland.

Symphysurina (Symphysuroides) expansa KOBAYASHI, new species

Plate III, figures 6a–b and 7.

Description:—Cranidium nearly as long as broad and regularly convex; glabella broad, expanded forward from the eyes; occipital margin more arcuate than the frontal margin of the cranidium; median tubercle located near the center; dorsal furrows traceable in the whole length of the glabella; eyes fairly large, located at the mid-length; fixed cheeks distinctly depressed below the glabella; facial sutures diverging forward from the eyes and recurved near the frontal margin; those behind the eyes diagonal.

Pygidium subovate, moderately convex, its length and breadth being in a ratio of 1: 1.5; axial lobe a third as wide as the pygi-

dium, distinctly elevated above the side-lobes, gradually tapering back and rounded off at a short distance from the posterior margin; three rings countable in two-thirds of its length; lateral lobes distinctly bent down in the outer half; only the first pleural groove distinct; test smooth.

Comparison:—Such a remarkable forward expansion of the cranidium and glabella is the feature not seen in any other species of *Symphysurina*. The pygidium is evidently longer than in *elegans* or *uncaspicata*.

Occurrence:—Loc. 24.

Symphysurina (*Symphysuroides*) *cfr. brevispicata* HINTZE

Plate III, figures 15–18.

1952. *cfr. Symphysurina brnvispicata* HINTZE, *Utah Geol. and Min. Surv. Bull.* 48, p. 236, pl. 3, figs. 9–17.

Occurrence:—Locs. 10b, 16, 22 and 23. The cranidia from these localities may be splitted into two or more species because there are some differences among them. But they belong probably to the same morphic group with *Symphysurina brevispicata* because they are found in association with free cheeks bearing short genal spines and spineless pygidia.

Symphysurina a and b spp.

Plate III, figures 10–14.

Like *elegans* the dismembered carapace of a sp. found at loc. 19 are pitted (Figs. 10–11). The broad cranidium with eyes in relatively posterior position is quite different from that of *elegans*, but looks similar to that of *uncaspicata*. The associated free cheek bears no spine at the genal angle. The pygidium from loc. 19 is triangular in outline. As its posterior part is broken, the presence or absence of the caudal spine is indecisive.

Much smaller cranidia in similar outline which are grouped in b sp. are found at locs. 2, 15 and 23, (Figs. 12–14). Their tests appear smooth. Three small pygidia from loc. 15 are semicircular in outline.

Occurrence:—Locs. 2, 15, 19 and 23.

Subfamily Ogygiocarinae RAYMOND, 1913

It is a remarkable fact that asaphids with caudal spines developed more on the Pacific than on the Atlantic side. As KAYSER (1895) has erected *Thysanopyge*, his *T. argentina* is a significant asaphid having minor spines, beside a long caudal one, by which the lateral margins of the pygidium are denticulated.

The occurrence of asaphids with caudal spines in western North America has long been known since the descriptions of 2 species of *Megalaspis* by MEEK (1873) and White (1877). The out-turn of the dorsal furrows in the rear part of the pygidium as typically shown by *Megalaspis belemnurus* WHITE is certainly an unusual feature. Therefore *Xenostegium* is a valid genus. It is, however, a heterogeneous aggregate, if all of WALCOTT's species are retained in it.

Xenostegium taurus WALCOTT was selected for the type of *Kobayashia* by HARRINGTON (1938). *Asaphus* (*Megalaspis*) *goniocerum* MEEK was referred to his *Trigonocerca* by ROSS. In addition *Kayseraspis* and *Trigonocercella* were erected by HARRINGTON (1938) and HINTZE (1952) respectively on *Kayseraspis asaphelloides* HARRINGTON and *Trigonocercella acuta* HINTZE. Thus there are 6 genera which have caudal spines. "*Xenostegium*" *euclides* WALCOTT and its allies cannot, however, be included safely in any of these genera or some others in the Atlantic province. The out-turn of the axial furrows in the pygidium is the unique feature of *Xenostegium*. In *Xenostegium franklinensis* CLARK and *X. acuminiferentis* (ROSS), however, it appears in the grown stage. In its youngster the axial lobe is directly produced behind into a caudal spine. In the middle age the root of the spine is expanded laterally as in *Megalaspis heros* DALMAN, (SCHMIDT, 1906, pl. VII, fig. 4a).

In the cranidium *Xenostegium* and even *Trigonocerca* are similar to *Bellefontia*. The pygidium of *Bellefontia* is broad and has an entire margin. In *Kayseraspis asaphelloides* the glabella narrows forward and is rounded at the front. The anterior protrusion of the cephalic outline is a remarkable feature of *Trigonocercella acuta*. The glabella is unfurrowed in these genera, while its posterior furrows are pitted in *Kobayashia*.

HARRINGTON considered that *Kobayashia* was derived from the *Megalaspis* stock and *Xenostegium* from *Kobayashia*, while *Kayseraspis* is a derivative from *Asaphellus*.

Megalaspis is a comprehensive genus in which not only the dorsal shield but also the hypostoma vary to a great extent. As clearly shown by Brögger and others, the posterior margin is entire in *planilimbata* (1), sinuated in V shape in *limbata* (2) and protruded into a median spine in *grandis lata* and *acuticauda* (3). The hypostomata of *Kobayashia* and *Kayseraspis* are allied to the last kind and at the same time to the hypostoma of *Asaphellus homfrayi* (SALTER) (LAKE, 1942) in the rounded lateral outline, although the median spine is absent in *homfrayi*.

The hypostoma of "*Xenostegium*" *euclides* WALCOTT appears to belong to the first kind of *Megalaspis*. The hypostoma of *Trigonocerca typica* is, like that of *limbata*, sinuated in form of V, but has a median spine. In *Trigonocercella acuta* which occurs in a higher horizon than *typica* the sinuation is developed into a deep U, lateral margins are more pointed than in *typica* and the median spine is absent. The hypostoma of *Bellefontia* is quite different from them in the well rounded anterior margin, subquadrate posterior outline, peculiar lateral wings and so forth.

In *Kobayashia taurus* as well as *Megalaspis acuticauda* the glabella is parallel-sided or somewhat expanded in its anterior part. It is contracted at the eyes in *K. lanceolata*. In *K. eudocia* it is expanded behind the eyes. Thus the glabellar outline varies to some extent in *Kobayashia*. The usual presence of pitted posterior furrows serves for its distinction from *Kayseraspis*, *Xenostegium*, *Trigonocerca*, *Trigonocercella* and also from *Asaphellus*.

Complete or nearly complete dorsal shields are known of *Kayseraspis asaphelloides*, *K. brackebuschi* (KAYSER) and *Bellefontia mcconnelli* (RAYMOND) and *B. ibexensis* HINTZE, but all others of these Pacific genera are represented by dismembered carapaces.

In the two species of *Kayseraspis*, the pygidium is fairly broad and rounded on the rear side; its axial lobe narrow, prominent, well segmented, outlined laterally by dorsal furrows and once rounded at the end but a short spine issues behind it.

The pygidia of *Trigonocera* and *Trigonocercella* are subtriangular; segmentation is quite obsolete; and the axial lobe not so distinct as and broader than that of *Kayseraspis*. The pygidium of *Trigonocercella acuta* is more triangular and a little longer than any of *Trigonocerca*. The pygidia of *Kobayashia taurus* and *Kayseraspis* (?) *euclides* are also triangular but their axial lobes are narrower and

more prominent than that of *T. acuta*.

With detached pygidia only (a, b, c, in figs. 8, 11, 14 on pl. VIII), it is very difficult to say their generic positions, because the above mentioned distinctions are not very sharp. Therefore the generic reference of incomplete asaphids is here made tentatively.

Genus *Bellefontia* ULRICH, 1924

1924. *Bellefontia* ULRICH in WALCOTT, *Smithson. Mics. Coll.* Vol. 75, No. 2, p. 54.
 1925. *Bellefontia* ULRICH in WALCOTT, *Ibid.* Vol. 75, No. 3, p. 69.
 1951. *Bellefontia* ROSS, *Peabody Museum Nat. Hist. Yale Univ. Bull.* 6, p. 79.
 1952. *Bellefontia* HINTZE, *Utah Geol. and Min. Surv.* 48, p. 140.

In the dorsal view this genus is similar to *Asaphellus* with which *Hemigyraspis* may be synonymized, because *Asaphus affinis* M'COY, the type species of *Hemigyraspis*, was synonymized with *Asaphellus homfrayi* (SALTER) by LAKE (1942). In *Bellefontia* the glabella is remarkably expanded forward as far as it overlaps the marginal groove. The anterior facial sutures are more widely divergent in *Bellefontia* than in *Asaphellus*. Their hypostomata are quite different from each other. There is no spine on the posterior margin; the posterior outline subquadrate; anterior margin well rounded; lateral wings remarkably bent back.

As suggested by its name, *Parabellefontia concinna* HINTZE is closely allied to *Bellefontia colliciana* (RAYMOND), but effacement of the dorsal relief is quite advanced in *Parabellefontia*.

Bellefontia platana KOBAYASHI, new species

Plate III, figures 2-5.

This species is represented by a detached cranidium, free cheek, hypostoma and pygidium. The dorsal shield figured out with them is remarkably flat. Cephalon exclusive of genal spines semicircular; marginal border ill-defined; glabella unfurrowed, slightly swelling up above cheeks and a frontal border, but its outline is not sharply defined except in the post-ocular part where dorsal furrows are fairly well impressed; palpebral lobes opposed at about the middle of the glabella; a very tiny median tubercle found on the glabella a little behind the eyes; eye-band on the free cheek well developed; facial sutures widely divergent forward from the eyes, but turned inward on the marginal border and meet with each other in front.

Pygidium semicircular; axial lobe narrow, elevated above slightly convex side-lobes; marginal border flat.

The hypostoma is not essentially different from those of *Bellefontia chamberlaini* CLARK and *B. ibexensis* HINTZE, but longer and the posterior outline is more rounded in this species.

The dorsal shield is remarkably convex, genal spine rudimentary, the pygidium longer and its axial lobe broader in *Parabellefontia concina* than in this species. *Symphysurina walcotti* KINDLE (1929) is represented by a pygidium resembling that of this species but the anterior margin is remarkably straight in this species.

Occurrence:—Loc. 15.

Bellefontia (?) aff. *collicana* (RAYMOND)

Plate V, figures 4-5.

1910. aff. *Hemigyraspis collicana* RAYMOND, *Ann Carnegie Mus.* Vol. 7, No. 1, p. 41, figs. 9-13.
 1924. aff. *Bellefontia collicana* ULRICH in WALCOTT, *Smithsonian Misc. Coll.* Vol. 75, No. 2, p. 54, fig. 3.
 1925. aff. *Bellefontia collicana* ULRICH, in WALCOTT, *Smithsonian Misc. Coll.* Vol. 75, No. 3, p. 72, pl. 23, figs. 1-6.

Three pygidia from loc. 3 are all similar to *Asaphellus* (?) *canadensis*, but they are more convex and their anterior margins a little arcuate. The axial lobe does not show the terminal swelling. The pygidia of *Hemigyraspis collicana* in RAYMOND's illustration have straight anterior margins and the one in fig. 9, on pl. 14 is evidently longer. The present pygidia agree better with ULRICH's than RAYMOND's, but the axial lobe in ULRICH's terminates at a short distance inside of the marginal border, while it reaches always to the inner margin of the border in the present ones.

It is very difficult to point out the generic position of such isolated pygidia. Their resemblance with the species from Pennsylvania might be superficial. *Hemigyraspis mcconnelli* RAYMOND (1913, 25) which belongs probably to *Bellefontia*, differs from *collicana* chiefly "in having a wider and less distinctly segmented axial lobe."

Occurrence:—Locs. 3 and 4.

Bellefontia (?) sp.

Plate V, figure 6.

This pygidium looks similar to *Asaphellus* (?) *canadensis* on one

side and *Bellefontia collieana* on the other. But the pygidium is broader than either one of them. Its convexity is intermediae between the two. The marginal border is narrower than that of *Bellefontia nonius* WALCOTT.

Occurrence :—Loc. 4.

Genus *Asaphellus* CALLAWAY, 1877

Asaphellus (?) *canadensis* KOBAYASHI, new species

Plate V, figures 1-3.

Description :—Cephalon semicircular except for a pair of genal spines; glabella long, cylindrical, subrounded in front, fairly convex, rather conspicuously inclined forward in the anterior third; no lateral furrows; occipital one strong on the cheeks, but almost indiscernible on the glabella; dorsal furrows narrow and nearly parallel to each other, but rather abruptly incurved at the anterior ends and become weaker along the arcuate frontal margin of the glabella; palpebral lobe of moderate size, semicircular, opposed at the mid-length of the glabella; fixed cheek anterior to the eye narrow, but that posterior to the eye is broad; frontal limb and border narrow and the latter subtriangular, slightly upturned and separated from the former by a narrow furrow. Free cheek gently inclined distally from the eye, moderately convex; marginal border narrow, flat and protruded into a genal spine of moderate length; eyes holochroal. Facial suture isoteliform, widely divergent from the median point of the border and from the lateral end of the frontal furrow, runs a little inward rather than the due backward; posterior branch of the suture sigmoidal, fairly transversal, and abruptly bent back at some distance from the genal angle.

Pygidium semicircular, slightly inflated; axial lobe about a fifth as broad as the pygidium, gradually tapering back in the anterior and middle parts but nearly parallel-sided or even somewhat expanded in the posterior part and abruptly rounded at the rear end, convex, and elevated above the pleural lobes; 5 or more rings countable on the conical parts of the axis, but the ring furrows are weak except the first one; pleural lobes nearly horizontal, but gently inclined near the marginal border, divided into 6 or 7 flattopped ridges by pleural furrows which are weak except the first one; marginal border narrow and depressed.

Test smooth.

Comparison:—The above description is based on a cranidium, free cheek and pygidium from loc. 20. The cranidium is the holotype.

The combination of these detached parts into a species seems quite reasonable because there is no other asaphid in the collection from loc. 20, except *Kayseraspis* (?) *eulides* which is much larger and quite different from this form.

The pygidium is very similar to that of *Bellefontia* and especially of *B. collicana* (RAYMOND). *B. chamberlaini* CLARK and *B. nonius* WALCOTT have broader marginal borders on their pygidia, although the present pygidium agrees better with *nonius* than *collicana* in the swelling of the terminal lobe. Its posterior protrusion, however, can hardly be seen in *nonius*. Furthermore it is noteworthy that the segmentation is distinct on the axis but quite obsolete on the pleural lobes in *Bellefontia*.

This cephalon is quite different from that of *Bellefontia*. It resembles ROSS' *Niobe* (?) sp. but the dorsal furrows are not so pronounced and its facial sutures distinctly isoteliform. The slight divergence of the anterior facial sutures and long cylindrical glabella are its significant features which are suggestive of *Asaphellus* alliance. In *A. homfrayi* (SALTER), however, the glabella is not so clearly defined, long enough to reach the frontal border and the eyes smaller and more antea.

In *A. catamarcensis* KOBAYASHI (1937) and *A. jujuyensis* HARRINGTON (1938) from Argentina dorsal and occipital furrows are fairly distinct. The eyes are located a little posterior to the middle of the cranidium in *Asaphellus* (*Asaphelloides*) *americana* KOBAYASHI, (1937).

It appears to be allied to *Asaphellus*, but the glabella is outlined more clearly by its own convexity and also by furrows. Though narrow, there is a frontal limb, which appears absent in *Asaphellus*. I could not find any genus to which this species can safely be referred. Judging from the size, the trilobite from loc. 20 could be an immature form.

Occurrence:—Loc. 20.

Genus *Xenostegium* WALOTT, 1924

1424. *Xenostegium* WALCOTT, *Smithson. Misc. Coll. Vol. 75, No. 2*, p. 60.
1925. *Xenostegium* WALCOTT, *Ibid. Vol. 75, No. 3*, p. 124.

1934. *Xenostegium* KOBAYASHI, *Jour. Fac. Sci. Imp. Univ. Tokyo, Sect. 2, Vol. 3, Pt. 9*, p. 557.
 1938. *Xenostegium* HARRINGTON, *Revista Mus. La Plata, (N. Ser.) Tom. 1*, p. 223.
 1951. *Xenostegium* ROSS, *Peabody Mus. Nat. Hist. Yale Univ. Bull. 6*, p. 100.

WALCOTT combined more than two groups of megalaspoids in this genus. *Xenostegium* specified by *Megalaspis belemnurus* WHITE is closely allied to *Bellefontia* in the cranidium or cephalon, but different in the pygidium in the adult stage. In *Xenostegium* it is triangular. Its axial furrows turn outward at the posterior end where the axial lobe becomes prominent and whence a caudal spine issues. This aspect is quite unusual among asaphid-pygidia, but ROSS (1951) and HINTZE (1952) have shown in *Xenostegium franklinensis* CLARK and *X. acuminiferentis* (ROSS) that this kind of pygidium grows from *Bellefontia*-like pygidium. In the grown stage the axial furrows become obsolete in their terminal part in *schofieldi*, *shepardi*, *kirki* and other species of *Xenostegium* but not in *Xenostegium douglasensis* WALCOTT. It could be a link between the two genera, because the outline of the pygidium is broad and the posterior spine small in *X. douglasensis*.

From these facts *Xenostegium* is thought to be closely related to *Bellefontia*. Unfortunately the hypostoma of *Xenostegium* is as yet uncovered. Its anterior outline suggested by the posterior margin of the doublure is somewhat different from that of *Bellefontia*. Furthermore the pygidium of *Xenostegium* in the middle stage of growth is quite similar to that of Megalaspids.

Genus *Kobayashia* HARRINGTON, 1938

1938. *Kobayashia* HARRINGTON, *Rev. Mus. La. Plata (N. Ser.), Tom. 1*, p. 224.

HARRINGTON founded this genus on *Xenostegium taurus* WALCOTT and referred *X. (?) sulcatum* WALCOTT and *X. (?) eudocia* WALCOTT to it. The narrow glabella, pitted posterior and occipital furrows and the anterior sutures forming a distinct ogive distinguish this genus from *Xenostegium*.

According to ROSS *sulcatum* is based on a deformed cranidium of *eudocia*. He tentatively referred *taurus* to *Xenostegium* and *eudocia* to *Asaphellus* with some reservation. They are, however, distinct from these suggested genera and belong most probably to *Kobayashia* together with the cranidium of *Macropyge gladiator*.

HARRINGTON considered that *Kobayashia* was derived from

Megalaspis stock. The aspect of its glabella is certainly similar to that of *Megalaspis acuticauda* ANGELIN, but the proportional size of the glabella to the cephalon is quite different between the two species.

A better concept of the genus is available from *K. lanceolata* described in this paper. The pleural lobes of the pygidium are smooth on the surface, but pleural and interpleural furrows are distinctly seen on the exfoliated surface. Its hypostoma is allied to that of *Megalaspis grandis* var. *lata* (BRÖGGER, 1886, pl. 2, figs. 26 and 26a).

Kobayashia lanceolata KOBAYASHI, new species

Plate IV, figures 1-3.

Description:—Cranidium nearly as long as wide; glabella strongly contracted at a point slightly posterior to its mid-length where eyes are opposed; its anterior part large, expanded forward and rounded in front; dorsal furrows pitted just behind the contraction; occipital furrow pronounced on the lateral sides, but weakened toward the axis; fixed cheek very narrow, but its posterior limb is well dilated laterally; eyes erected and close-set to the glabella; frontal rim fairly large, nearly flat and lanceolate; free cheek with a depressed marginal border which is probably produced into a genal spine; facial sutures a little divergent in front of the eyes, intramarginal on the border and meet en ogive in front; their posterior branches widely divergent.

Associated hypostoma as long as broad; anterior margin well rounded and alate at the lateral ends; central body broad, somewhat ovate, strongly vaulted and incised in the posterior by a pair of pits which are triangular and remarkably pronounced just inside of the marginal groove; marginal furrow deep; lateral border inclined inward, broad and well rounded; a tiny posterior spine issues from the border.

Pygidium semi-parabolic; axis conical, a fifth as broad as the pygidium, distinctly elevated above gently convex pleural lobes; four or five anterior rings clearly separated from one another by transverse furrows; marginal rim narrow and crossed by a narrow post-axial spine.

Comparison:—Except for the frontal brim which is longer and

less expanded laterally than in *taurus*, this cranium is quite similar to that of *Kobayashia taurus* (WALCOTT, 1925, ROSS, 1951) and also to the cranium of "*Macropyge*" *glandiator* (ROSS, 1951). *Kobayashia eudocia* (WALCOTT) is represented by a fragmentary cranium which is not much different from this species, although a very close comparison cannot be made. The crania which ROSS called *Asaphellus* (?) *eudocia* are different from this species in the presence of a distinct marginal furrow.

The illustrated pygidium is incomplete but enough to figure out its complete form. Another pygidium shows distinct segmentation on its exfoliated surface. Pleural and interpleural furrows typical of *Megalaspis*, are distinctly impressed in the latter pygidium but these furrows are not seen in the surface of the former pygidium. If these pygidia are found isolated from the cephalon, they may be identified with "*Xenostegium*" *douglasensis*. They are also similar to the pygidium of *Xenostegium* (?) *paradouglasensis* KOBAYASHI, although the axial lobe is more convex and the marginal rim broader. The cranium of *douglasensis* is quite different from that of this species, and appears to belong to either *Xenostegium* or *Bellefontia*.

Occurrence :—Locs. 4. and 14.

Genus *Kayseraspis* HARRINGTON, 1938

Kayseraspis (?) *euclides* (WALCOTT)

Plate IV, figures 4–12, Plate V, figures 8–10, (?) 22–23

1925. *Xenostegium euclides* WALCOTT, *Smithson. Misc. Coll. Vol. 75*, p. 126, pl. 24, figs. 13–14.
 1925. *Xenostegium albertensis* WALCOTT, *Ibid.* p. 125, pl. 24, figs. 10–11.

Description :—Cranidium nearly as long as broad and slightly inflated; glabella subcylindrical, about two-thirds as long as the cranidium, slightly elevated above the surroundings, no lateral or occipital furrow; dorsal furrows fairly distinct behind the eyes; axial ridge occasionally impressed, terminates at a tiny median tubercle which is located far back near the posterior margin; eyes close-set to the glabella at its mid-length; posterior limb of fixed cheek narrower than the glabella, truncated vertically at the lateral end; frontal brim flat or somewhat concave, protruded and pointed forward; facial sutures divergent from the eyes and gradually incurved near the cephalic margin; posterior branch of the suture gently inclined laterally from the eye but becomes subvertical near the end.

Pygidium triangular, gently convex, bordered by a narrow, nearly flat or slightly concave border; axial lobe as broad as a fifth or less of the pygidium, conical and especially prominent near the posterior end where it is abruptly rounded off; pleural lobes gently inclined laterally; caudal spine extending through the posterior border.

Observations:—A hypostoma procured from loc. 4 is similar to WALCOTT's hypostoma of *euclides*. The central body is subelliptical, but incised in the hind part by a pair of depressions. The marginal border is thick on the postero-lateral sides. The posterior margin is straight and transversal and there is no spine.

The above description of the crinidium is chiefly based on the specimen from loc. 20. In addition there are a cranidium from loc. 3 and another from loc. 4 which belong to the same kind. The glabella is relatively large and the eyes are located more posteriorly in the larger cranidium.

There are many pygidia which were collected from locs. 3, 4, 11, and 20. They are similar in the general outline of the pygidium but somewhat different in the dorsal relief and the development of the caudal spine. Through their comparison it is found as a general tendency that the axial lobe is more prominent, the marginal border better defined and the segmentation more distinctly impressed in small pygidia than in large ones. The segmentation is distinct in WALCOTT's type pygidium of *euclides* which is small but obsolete in his type pygidium of *albertensis* which is larger. The caudal spine is well developed in two small ones from locs. 11 and 20 and a large one from loc. 3, but rudimentary in the largest one from loc. 3.

Because the convexity varies to some extent among the pygidia at hand, I think, the type pygidium of *albertensis* may be no more than a large strongly convex form of *euclides*.

It is probable that two or more species are included here, but those from the four localities are thought to belong to the same kind. The pygidia from loc. 17 are similar to them but more rounded.

Comparison:—The hypostoma of this species is similar to that of *Megalaspis acuticauda* ANGELIN (SCHMIDT, 1906, pl. 5, figs. 6-7), those of *Asaphellus homfrayi* (SALTER) (LAKE, 1942, pl. 45, figs. 1, 5, 6, 8.) and *Kayseraspis asaphelloides* HARRINGTON (1938, pl. 10, figs. 2, 15), but a tiny posterior spine usually present in these species is absent or unknown in this species. The glabella is ill-defined as in

Asaphellus, but the triangular pygidium with a caudal spine is strongly suggestive of its alliance with *Megalaspis*.

Occurrence:—Locs. 3, 4, 11, 20 and probably 17.

Kayseraspis (?) sp.

Plate IV, figures 13–14.

This is quite similar to the preceding, but (1) the axis is less prominent, (2) its segmentation more obsolete, (3) the marginal rim broader and (4) the caudal spine issuing from the rim. The segmentation is, however, clearly seen in the exfoliated surface of a large pygidium.

In the unfurrowed axial lobe this is more like the pygidium of “*Xenostegium*” *douglasensis* than the preceding. In the nature of the caudal spine it agrees well with the two species of *Kayseraspis* from South America. The axial furrows are, however, much weaker in this than in those species.

With the pygidium only no decision of such an asaphid can be made as to its generic determination.

Occurrence:—Locs. 1 and 11.

Genus *Columbicephalus* KOBAYASHI, new genus

This genus is founded on *Columbicephalus macrops*, nov. having the oblong glabella, large semicircular palpebral lobe attached to its posterior and upturned triangular frontal brim. It is similar to certain primitive asaphids. For example, *Niobe primoeva* WESTERGÅRD (1922, pl. 2, fig. 25) which was later called *Niobella aurora* by the author (1939) reveals some similarity in the pre-ocular aspect. This shows some resemblance also with *Asaphellus*. In this genus, however, the palpebral lobe is extraordinarily large as in *Haniwa* and its allies and located posteriorly. In the preglabellar aspect it reminds one of *Lioparia* LORENZ (i.e. *Yokusenina* KOBAYASHI) (1937, 38). It is not improbable that it is a terminal form of the group which includes *Haniwa* and *Lioparia*. Further observations are given in the description of the type species.

Columbicephalus macrops KOBAYASHI, new species

Plate V, figures 7a–b.

Description:—Glabella large, oblong, its posterior part being

somewhat angulated along the axis and provided with two pairs of shallow depressions on the two sides of this blunt keel; occipital furrow shallow and relatively broad; palpebral lobe large, semicircular, opposed in the posterior to the middle of the glabella and extended horizontally; glabella abruptly inclined in the anterior toward the deep marginal groove whence the frontal brim is bent upward and forward; facial sutures nearly parallel to each other in the front of the eyes and run across the frontal brim diagonally to meet each other at the median point. Test smooth.

Occurrence:—Loc. 10a.

Subfamily Asaphinae GIRICH, 1908

Genus *Kirkella* KOBAYASHI, 1942

Kirkella cfr. *vigilans* (WHITTINGTON)

Plate V, figures 12–17, plate VIII, figure 6.

1948. cfr. *Ptychocephalus vigilans* WHITTINGTON, *Jour. Pal.* vol. 22, p. 256, pl. 82, figs. 1–7, pl. 83, figs. 1–11.

The pygidium is pentagonal and fairly convex; axial lobe elevated a little above the general convexity of the pygidium; segmentation indiscernible on the surface except the first pleural furrow which is, however, strong; facet in front of it steeply inclined and extending along the lateral margin as far as the lateral angle; marginal border almost as broad as pleural lobes. It agrees best with *Kirkella vigilans* among the six species of the genus.

Beside some pygidia there are a cranidium and 2 free cheeks from loc. 3. The glabella is long, subquadrate, unfurrowed and slightly elevated; palpebral lobe large, close-set to the glabella; frontal border slightly depressed; facial suture apparently isoteli-form.

A small pygidium, 2 mm. long, which is presumed to belong to this species has no postero-lateral angulation. The axis is more prominent and the border more strongly depressed than the adult form.

A pygidium from loc. 17 is a little smaller than the one in fig. 15. They are almost the same in outline. The axial lobe is more prominent and the marginal border more depressed in the former than in the latter. In these respects the former resembles the pygidium of *Kirkella declevita* ROSS.

There are some hypostomata from loc. 13 which are thought to belong probably to *Kirkella*, but they are different from those of *vigilans*, *declevita* and *yersini* in the broader and more rounded outline. If this kind of hypostoma goes with these parts of the dorsal shield, the species is evidently distinct from any of the known *Kirekellas*.

Occurrence:—Locs. 13 and 17.

Genus *Protopresbynileus* HINTZE, 1954

Protopresbynileus (?) aff. *willdeni* (HINTZE)

Plate V, figures 18–19, plate VIII, figure 15.

1951. aff. *Pseudonileus willdeni* HINTZE, *Utah Geol. Min. Surv. Bull.* 48, p. 224, pl. 15, figs. 14–17.

1954. aff. *Protopresbynileus willdeni* HINTZE, *Jour. Pal.* Vol. 28, p. 119.

Though a little broader, the pygidia from loc. 14 are allied to *P. willdeni* in its gentle convexity, short triangular axial lobe, absent marginal border and particularly in the presence of a ventral node on the doublure. The inner margin of the doublure is remarkably sinuated along the axis. Internally the doublure is pitted on the axial line at a point a little behind the middle.

A small pygidium of the same kind is contained in the collection from loc. 4.

Occurrence:—Locs. 4 and 14.

Family Bathyruridae WALCOTT, 1886

Genus *Gonioteloides* KOBAYASHI, new genus

Diagnosis:—Pygidium triangular, devoid of either marginal rim or border, but there is a pseudoborder which is a doublure extending downward or even outward from the peripheral angulation of the dorsal shield; axial lobe composed of 4 rings and a short caudal spine.

Type species:—*Gonioteloides monoceros* KOBAYASHI, new species.

Remark:—In the triangular outline of the pygidium and the caudal spine directly issued from the axial lobe this genus resembles *Goniotelus* ULRICH, 1927, *Eleutherocentrus* CLARK, 1935 and *Goniotelina* WHITTINGTON and ROSS, 1953, whose types are *Bathyrurus perspicator* BILLINGS, *Eleutherocentrus petersoni* CLARK and *E. williamsoni* ROSS respectively. These species, however, have more numerous axial rings and a longer and more slender caudal spine.

G. monoceros looks especially similar to *G. williamsoni*, but interpleural furrows are present in that species. ROSS states that *G. williamsoni* has a smooth marginal rim. The presence of the pseudoborder and the absence of the marginal rim are most distinctive of this genus. Its family reference cannot be warranted until its cephalon will be found.

Distribution :—Lower Ordovician; western Canada.

Gonioteloides monoceros KOBAYASHI, new species

Plate VI, figures 17a-b and 18a-b.

Description :—Pygidium subtrapezoidal in outline, gently convex; periphery sharply angulate; pseudoborder steeply inclined; axial lobe one third as broad as the pygidium, delimited by a dorsal furrow on each side, divided by three furrows into three rings and a terminal lobe which is in turn divided again by a remarkably arcuate shallow furrow into an anterior ring and a posterior spine; the fourth ring somewhat broader than the third ring; these four rings nearly equal in length; the spine short, lenticular in cross section, stout and gently sloping down, following the general curvature along the axis; side lobes divided into four ridges by three distinct furrows; the first ridge corresponding to the anterior band of the first pleura, roof-shaped with its summit near the first furrow and its anterior slope wide and concave; succeeding three ridges gently convex, about the same in length but their breadth is reduced abruptly one after another and sharply truncated along the periphery; irregular fine subparallel striae running along the periphery and extend back along the lateral margin of the spine; pseudoborder extends from the periphery outward and downward, undulated and broadened on the two sides of the caudal spine; accordingly the outline of the pygidium proper triangular whereas its outline inclusive of the pseudoborder is trapezoidal; below the spine the margin of the doublure rises up in form of a broad cusp. Test smooth.

Observation :—On the broken antero-lateral margin of a pygidium from loc. 19 the apparent border which is called a pseudoborder in the above description is known to be the doublure which is extended from the periphery of the dorsal shield distally, instead of proximally as usual. This is understood from the facts that the pseudoborder in its section is not recurved inward at the end and that subparallel

but irregularly inosculating lines typical of the doublure are usually seen in the part of the pygidium.

Occurrence:—Locs. 2 and 19.

Gonioteloides punctatus KOBAYASHI, new species

Plate VI, figures 19a-b.

A large pygidium is diagnostic of the genus but differs from the preceding in the points as follows:

- (1) Evenly convex pygidium without difference in convexity or prominence between the axial and pleural lobes.
- (2) Weakness of axial and transversal furrows.
- (3) Broader axial lobe relative to the pleural ones.
- (4) Equal strength of the fourth to the third ring furrow.
- (5) Similar outline of the third ring to the precedings.
- (6) Pitted test, externally as well as internally.
- (7) Subvertical doublure, or pseudoborder.

Furthermore, as can be judged from its left margin, the caudal spine is more stout in this than in the preceding species.

Occurrence:—Loc. 7.

Genus *Licnocephala* ROSS, 1951

Licnocephala longa KOBAYASHI, new species.

Plate VI, figure 16; plate VIII, figure 13.

Two pygidia from loc. 13 are similar to those of *L. bicornis* ROSS and *L. (?) cavigladius* HINTZE that they are thought congeneric.

It is closer to HINTZE's than ROSS' but still different in taller and triangular outline. The axial lobe which is composed of 4 rings and a long terminal lobe, is evidently longer than the axes of those two species. There are four sets of pleural and interpleural furrows. The pleural furrows are confined to the gently convex inner part, but the interpleural ones are extended far into the brim which is, as in the Dikelocephalidae, very broad and flat or even more or less concave. According to ROSS (1953), *Licnocephala* is probably a bathyurid trilobite.

An incomplete pygidium of *Bathyurellus* sp. described by POULSEN (1937) from the Cape Weber formation in East Greenland bears similarities to this species, but its outline is longer than this.

Occurrence:—Loc. 13.

Genus *Lachnostoma* ROSS, 1951*Lachnostoma* (?) sp.

Plate V, figure 11.

An asaphoid cranidium with a long glabella, constricted at the eyes; dorsal furrows strong behind the eyes but become weak in their front. From weak convexity however, it is justified that the glabella is expanded and rounded forward. On the exfoliate surface a distinct axial ridge extends as far back as a prominent tubercle. Palpebral lobes erected at a place about the mid-length of the glabella. Facial suture semicircular in front of the eye.

The glabella in this species is unusually depressed, but the cranidium looks similar to *Lachnostoma latucelsum* ROSS and also *Hoekaspis schlagintweiti* HARRINGTON and LEANZA in some aspects or others. The specimen is too poorly preserved to say much of its taxonomy.

Occurrence:—Loc. 13.

Order Conocoryphida SWINNERTON, 1915

Family Ptychoparidae MATTHEW, 1887

Subfamily Eulominae KOBAYASHI, new subfamily

Euloma ANGELIN forms a group of the Ptychoparidae with *Pareuloma* RASETTI and *Eulomella*, nov. Their dorsal shields are typical of ptychoparoids, but their glabellae are shorter and more quadrate and their pygidia shorter and smaller, if compared with *Ptychoparia*. There are usually two pairs of strong lateral furrows on the glabella and the anterior ones very weak when there are three pairs of furrows. The frontal limb and rim are convex and the groove between them is frequently pitted. The pitted frontal groove is unusual in the Ptychoparidae but common in these genera. The pits are, however, absent in *Euloma laeve* ANGELIN and *Pareuloma impunctata* RASETTI.

The eyes at the mid-length of the cranidium and the divergent preocular sutures exclude the group from either the Olenidae or the Calymenidae. As pointed out by FRECH (1898), *Euloma* resembles *Phalostoma*, but still it is a ptychoparid rather than a calymenid.

The sizes of the glabella and eyes are different among the three

genera of the Eulominae. They are small in *Pareuloma*. The glabella is much broader in *Eulomella* than in *Euloma*. The preglabellar swell as seen in some ptychoparid-genera is sometimes met with in a *Euloma* or a *Pareuloma*.

The anterior branches of the facial sutures are divergent in Scandinavian *E. laeve*, *E. ornatum* ANGELIN, *E. primordiale* WESTERGÅRD (1909), British *Conocoryphe monile* SALTER and Bavarian *Conocephalites geinitzi* BARRANDE. *Euloma granulatum* RŮŽIČKA is quite different from them in the convergence of the sutures and diminution of the eyes. In *Euloma mitratum* RŮŽIČKA (1926) for which *Eulomina* was instituted by the author (1931), the glabella is subtriangular, instead of subquadrate. In these Bohemian species the pygidium is emarginated at the rear where the post-axial ridge terminates. *Euloma inexpectatum* HOLUB (1912) is represented by a more normal pygidium, but without interpleural furrow.

POMPECKJ and BRÖGGER considered *Calymenopsis filacovi* M. CHALMAS and BERGERON to be a member of *Euloma*. Like *Eulomella* it has the eyes close to the glabella, but the glabella is not so large as that of *Eulomella*. This as well as RŮŽIČKA's two species are not typical of the Eulominae, but may be included in the subfamily as aberrant forms.

I have once combined *Euloma* and *Loganellus* with *Richardsonella* in the Richardsonellinae of the Dikelocephalidae (1935), but as discussed lately (1953), it is more reasonable to refer the Richardsonellinae, s. str. to the Kainellidae. Neither *Euloma* nor *Loganellus* belongs to the subfamily in the restricted sense. *Loganellus* is closely related to *Levisella* RASETTI, but not so much with *Euloma*. They have narrower fixed cheeks than the Eulominae. In other words, the glabella is more developed in them than in the Eulominae. The eyes are generally small in them. The thorax is composed of 13 segments in *E. monile* and 12 segments in *Loganellus logani* (DEVINE). The pygidium is larger and the axis provided with more segments in the latter than in the former. *Loganellus* and its allies were probably derived from the common stock with *Euloma*, but they appears to represent an Upper Cambrian branch by themselves.

Genus *Eulomella* KOBAYASHI, new genus

Similar to *Euloma* but the glabella is much broader and provided

with three pairs of lateral furrows.

Type species:—*Eulomella mckayensis* KOBAYASHI, new species.

Distribution:—Lower Canadian; western Canada.

Eulomella mckayensis KOBAYASHI, new species

Plate VI, figure 3; plate IX, figure 1.

Description:—Cranidium broad; glabella subquadrate, convex and provided with three pairs of lateral furrows; eyes large connected with the glabella by palpebral ridges; frontal limb large, vertically striated; frontal rim convex; frontal groove pitted; anterior facial sutures slightly divergent; median tubercle present on the occipital ring.

Comparison:—This is allied to *Euloma* more closely than any Canadian trilobite which I know of. It agrees with *Euloma* in major aspects, but the glabella is much broader in this than in *Euloma*. In fact it is twice broader than a fixed cheek at the eye. It is not expanded in the middle and rounded at the antero-lateral corners. The posterior furrows on the glabella are not geniculate; dorsal furrows not pitted at the anterior end; cheeks not elevated toward the eyes so highly as in *Euloma ornatum* ANGELIN.

The eyes are imperfectly preserved, but can be judged as large as those of that species. The eye ridges are weak, but well marked from the depressed frontal limb. How long is the posterior limb of the fixed cheek, is indeterminable, because it is broken off.

Occurrence:—Loc. 18.

Subfamily Elviniinae KOBAYASHI, 1935

Genus *Neotaenicephalus* KOBAYASHI, new genus

Diagnosis:—Cranidium subtrapezoidal, strongly convex, steeply inclined laterally; glabella of medium size, truncato-conical, clearly defined by dorsal furrows, but devoid of lateral furrows; eyes at the mid-length, moderate in size; no distinct eye-ridge; frontal limb crossed by longitudinal striae; frontal rim nearly flat.

Type species:—*Neotaenicephalus obsoleta* KOBAYASHI, new species.

Remark:—This is similar to *Taenicephalus*, *Conaspis*, *Elvinia* and *Moosia* and agrees better with the former two than the latter two in size. The complete obsoletion of lateral furrows on the surface is

its distinction from all of these genera. It is, however, probable that it was derived from *Taenicephalus* by effacement of the furrows.

Distribution :—Lower Ordovician ; western Canada.

Neotaenicephalus obsoleta KOBAYASHI, new species

Plate VI, figures 12a-b; plate IX, figures 9a-b.

Description :—Cranidium somewhat trapezoidal in outline and remarkably convex ; glabella medium in size, truncato-conical, unfurrowed except the occipital one ; its breadth almost the same as the length of the glabella exclusive of the neck ring, but reduced to a half at the front ; occipital furrow undulated with forward convexity in the middle and with forward bending near the lateral ends ; occipital ring slightly thickened in the middle part ; circumglabellar furrows deep and pitted at the antero-lateral angles ; eyes of medium size, located at about the mid-length of the cranidium and raised to the same height with the top of the glabella ; vestige of the eye-line seen only near the anterior end of the eye ; fixed cheek at the eye half as broad as the glabella ; its posterior limb well developed and steeply inclined laterally ; frontal limb convex, as wide as the fixed cheek at the eye, abruptly bent down in front of the eye and striated faintly by longitudinal lines ; frontal rim a little narrower than the limb and nearly flat ; facial suture directed a little laterally than to the due front but incurved after crossing the marginal furrow ; its posterior branch somewhat sigmoidal and abruptly bent back where it crosses the posterior rim which is thickened distally. Test smooth except the frontal limb.

Occurrence :—Loc. 24.

Genus *Vermilionites* KOBAYASHI, new genus.

Diagnosis :—Cranidium with a large truncato-conical, strongly convex and unfurrowed glabella, large eyes and narrow frontal limb and fixed cheek and thick convex frontal rim.

Type species :—*Vermilionites bisulcatus* KOBAYASHI, new species.

Remark :—This looks like a Cambrian rather than an Ordovician trilobite. It has the cranidium resembling *Maladia*, and *Resseraspis*, but the eye-bands are much larger, the frontal rim is thicker and the glabella in proportion to the cranidium smaller, if *Vermilionites*

is compared with *Maladia*. In addition to these distinctions the presence of the eye-ridge, convex frontal rim and pustulate frontal limb distinguish this genus from *Neotaenicephalus*.

Incidentally, *Resseraspis* is more allied to *Maladia* than *Lecanopyge* in the cranidium. Perceptible differences of the first from the second are diminution of the eyes and their approach to the glabella. In *Lecanopyge expansa* RAYMOND (1937) the glabella is remarkably expanded postally, frontal limb quite reduced and the frontal rim upturned. The pygidium on which *Resseraspis carinata* RASSETI (1945) was based, however, can easily be distinguished from *Maladia* and *Lecanopyge* by its post-axial ridge and entire margin of the pygidium.

V. bisulcatus is found together with *Leiostegium* (*Evansaspis*) *glabrum* at loc. 8, while RAYMOND's cranidium of *Crepicephalus* sp. indt. (1925, pl. 2, fig. 4.) is found associated with *L. (E. ?) ceratopygoides*. His cranidium, 4 mm. long, may be an immature one possibly of this genus, because it bears several characteristics of this genus. It, however, has "a pair of pits in the circumglabellar furrow near its anterior end," and "obscure traces of three pits" in the frontal furrow with which he suggested *Crepicephalus* for it.

These pits are however, so weak that they are unrepresented in the illustration. The eye-ridges are apparently absent and the eye-bands so far preserved in the specimen look smaller than those of the type species. Therefore it needs more materials to confirm its generic position:

Distribution:—Lower Ordovician; western Canada.

Vermilionites bisulcatus KOBAYASHI, new species.

Plate VI, figure 4; plate IX, figure 2.

Description:—Glabella large, truncato-conical, as long as broad, strongly convex, surrounded by deep dorsal furrows; its frontal margin almost half as broad as the occipital ring; no lateral furrows; occipital furrow deep; eye-band very large, occupying the middle half-length of the cranidium and connected with the glabella by a distinct eye-ridge; fixed cheek at the eye half as broad as the glabella; frontal limb and rim strongly convex, the former being only a little longer than the latter and they are separated from each other by a deep furrow; the rim somewhat narrows laterally; facial

sutures a little divergent in the anterior to the eyes. Test smooth except for the preglabellar field where some pustules are present.

Comparison:—It is not unlike paucipustulate forms of *Hystriacus*, *H. politus* ROSS, for example. But this is, I think, unrelated to the Solenopleuridae because the glabella is not so ovoid as usual in the family. In this species the frontal rim is arched medially but not very strongly. It has a pronounced eye-ridge which is absent in *Hystriacus*.

Occurrence:—Loc. 8.

Family Solenopleuridae ANGELIN, 1854.

Genus *Hystriacus* RAYMOND, 1913.

Hystriacus platypleurus KOBAYASHI, new species.

Plate VI, figure 6.

Pygidium semicircular; pleural lobes horizontal in the major part, but abruptly sloping down near the narrow flat marginal border; axial lobe as wide as the pleural platform, composed of 4 rings and a terminal lobe the last of which lies on the peripheral slope and abruptly tapers back; four pleural furrows radiate from the axial lobe; interpleural furrows absent; marginal border by no means arched up at the rear; test with fine granules.

Hystriacoid cephalae are now splitted into *Hystriacus*, *Parahystriacus*, and a few others, but their corresponding distinction on the pygidia is not yet well known. By this reason this pygidium is referred to *Hystriacus*, s.l.

In the collection from loc. 2 there are three kinds of pygidia which bear hystriacoid lookings. This pygidium is similar to *Dimeropygiella eos*, but the terminal lobe is not bisected and the interpleural furrows are effaced.

Occurrence:—Loc. 2.

Hystriacus cfr. *genalatus* ROSS

Plate VI, figures 1-2.

1951. cfr. *Hystriacus genalatus* ROSS, *Peabody Mus. Nat. Hist. Bull.* 6, p. 40, pl. 8, figs. 1-13, pl. 9, figs. 1-13, 17-19.
1952. cfr. *Hystriacus genalatus* HINTZE, *Utah Geol. and Min. Surv. Bull.* 48, p. 164, pl. 6, figs. 1-6.

A cranium and free cheek both having similarly granulate tests are found close-set on a piece of limestone. Glabella ovoid, strongly vaulted, devoid of lateral furrows; circum-glabellar and occipital furrows very strong; occipital ring convex and thickened in the middle; fixed cheek strongly convex and narrows at the point of the eye; ocular ridge indistinct, but apparently present; frontal limb and rim narrow, convex and separated from each other by a furrow.

The preglabellar area is poorly preserved in the cranium, but the free cheek shows clearly a raised lateral rim, strong marginal furrow and medium sized eye. In its width this form fits evidently better with *H. genalatus* than with *H. paragenalatus* Ross.

Occurrence:—Loc. 24.

Hystericurus sp.

Plate VI, figure 8.

A small pygidium twice broader than long, sublenticular in outline; posterior margin transversal or slightly sinuate; axial lobe a fourth as wide as the pygidium, strongly convex, composed of 3 or more rings and a terminal lobe which is abruptly rounded off at a short distance from the posterior margin; pleural lobe moderately convex, divided into 3 pleurae by furrows which are each divided into two tuberculate ridges by a secondary furrow; marginal border concave, depressed and narrowing posteriorly.

Occurrence:—Loc. 22. No other part of a hystericuroid is found in the collection from this locality.

Hystericurus (?) sp.

Occurrence:—An imperfect cranium of a hystericuroid is found contained in the collection from loc. 23. It is granulated. It is quite distinct from *Hystericurus* cfr. *genalatus* in the more quadrate and less convex glabella and distinct lateral furrows.

Genus *Parahystericurus* Ross, 1951

Parahystericurus (?) sp.

Plate VI, figure 7.

Pygidium subtriangular, twice broader than long; axial lobe conical, half as broad as the pleural lobe, composed of 3 rings and a

terminal lobe; pleural lobe flat, subhorizontal on the inner side but steeply inclined on the outer; three interpleural furrows running across the lobe in crossing the marginal groove; first pleural furrow strong on the flat inner portion, but the succeeding ones are very weak; pleural ribs become prominent at the boundary between the inner and outer portions; test granulose.

This pygidium bears common features with Ross' pygidia in figs. 6, 11 and 15 (from E zone) and in figs. 33 and 36 (from F zone) on pl. 19 (1951). The author noted that the former of the two is possibly referable to *Parahystericurus carinatus*. The present one is closer to the latter one in the broad outline with the straight anterior margin, (see also HINTZE, 1952, pl. 8, figs. 13a-b), but still different in the oblique truncation at the lateral ends of the anterior margin.

Occurrence:—Loc. 2. No hystericuroid cranidium is found in the collection from this locality.

Genus *Clelandia* COSSMANN, 1902

Clelandia (?) sp.

Plate VI, figures 5a-b.

Pygidium broad, somewhat elliptical in outline; axial lobe a fourth of the pygidial breadth, subcylindrical, but abruptly narrowing at the rear and divided into 4 rings or so; pleural lobes horizontal on the inner side, but gradually curving down on the outer; pleural and interpleural furrows of similar strength running from the axis to the periphery; pleural ribs tuberculate on the top; no marginal border; marginal part subvertical.

This pygidium resembles that of *Clelandia utahensis* ROSS (1951, pl. 29, figs. 4, 6, 7; HINTZE, 1952, pl. 4, figs. 5a-b) in the curvature of the pygidium and the mode of segmentation, but is much broader and its axis narrower.

Occurrence:—Loc. 2.

Genus *Dimeropygiella* ROSS, 1951

Dimeropygiella eos KOBAYASHI, new species

Plate VI, figure 10.

Description:—Pygidium strongly convex, about twice broader than long; anterior margin truncated obliquely on the lateral side;

lateral margin well rounded; posterior margin nearly straight; axial lobe conical, elevated above pleural platforms, composed of 5 rings and a triangular terminal lobe; fifth one divided into two buttons by a mesial depression; terminal lobe faintly outlined and sloping down from the fifth ring; dorsal furrows distinct as far back as the fifth ring whence they become very weak; pleural lobes horizontal on the proximal side, but steeply inclined on the distal side, divided into ridges by 4 strong pleural furrows which are somewhat broadened in the distal part beyond the periphery of the platforms; interpleural furrow shallower than the pleural one but still quite distinct on the second ridge; marginal rim narrow, subhorizontal and not bent up at the rear; axial rings and pleural ridges tuberculate but furrows and marginal rim are smooth; tuberculation pronounced along the flexed zone between the platform and marginal slope.

Comparison:—At a glance it reminds me of *Hystricurus*, but certain significant characteristics are quite suggestive of *Dimeropygiella*. Namely, the most posterior axial ring is bisected and pleural lobes from platforms on the proximal side.

The terminal lobe of the axis is obscure in *D. caudanodosa* ROSS and *D. blanda* HINTZE, but in *D. ovata* HINTZE it is clearly defined on the two sides by profound grooves. Undivided rings are 3 in *ovata* and *blanda*, 5 in *caudanodosa* and 4 in this species. Pleural furrows of this pygidium are, however, not so deep as in those species of *Dimeropygiella*, but more like those of *Hystricurus*. In the outline of the pygidium it is more allied to the latter than the former genus.

It was shown by ROSS (1953) that the arrangement of pustules on the glabella and its lateral sides in the immature stage of *Dimeropygiella caudanodosa* is similar to that found in immature *Hystricurus* and *Parahystricurus*, while in the possession of a rostral plate it agrees with *Dimeropyge* and *Tornquistia*. The median spine of the plate is, however, its speciality. It is probable that *Dimeropygiella* was derived from *Hystricurus* by convergence of the anterior facial sutures, specialization of the pygidial axis and so forth.

Occurrence:—Loc. 7.

Family Emmerichellidae KOBAYASHI, 1935

Genus *Metabowmania* KOBAYASHI, new genus.

Diagnosis:—Cranidium distinctly but gradually geniculated at

about a third from the base; glabella very short, ovate, strongly convex and unfurrowed, but the occipital ring is clearly defined by a furrow; eyes medium sized; ocular ridge indiscernible; frontal brim very large, as long as the glabella; frontal rim wire-like and a little arcuate.

Type species :—*Metabowmania latilimbata* KOBAYASHI, new species.

Remark :—It has several characters common with *Bowmania*, but the latter has two pairs of short glabellar furrows, distinct eye ridge and the well rounded frontal outline suggesting that the free cheek is much smaller than that of *Metabowmania*.

In *Stenocombus princeps* RAYMOND (1937) the facial sutures are convergent forward and the glabella is cylindrical, the frontal rim thicker and frontal limb shorter than in *Metabowmania*. Nevertheless they may be related to each other.

As noted elsewhere (KOBAYASHI, 1934), *Leptopilus declivis* RAYMOND belongs most probably to the Emmerichellidae. It can easily be distinguished from *Metabowmania* by its slender cylindrical glabella, presence of the median tubercle on the occipital ring and wide divergence of the anterior facial sutures.

I think, however, that *Leptopilus* and *Stenocombus* are allied to *Bowmania*, *Metabowmania* and *Probowmania* as indicated by coincidence in some major characteristics.

Distribution :—Lower Ordovician; western Canada.

Metabowmania latilimbata KOBAYASHI, new species.

Plate VI, figure 13; plate VIII, figure 9; plate IX, figures 7a-b.

Description :—Cranidium gently convex, but bent down more or less abruptly in the posterior to the middle; glabella small, elongately ovate, bulbous and clearly outlined by deep furrows, but having no lateral ones; occipital ring separated from the glabella proper by a deep furrow and thickened toward the axis; fixed cheek nearly as wide as the glabella; eyes fairly large, located a little anterior to the middle of the glabella and widely apart from the glabella; ocular ridge absent; frontal brim large, gently convex, gradually inclined forward and rather abruptly bent down near the lateral ends; frontal rim wire-like, separated from the frontal limb by a narrow furrow; facial suture straight forward from the eye but recurving abruptly on the rim. Test smooth.

Observation:—A free cheek found in the same slab from loc. 12 with an imperfect cranidium of this species has a genal spine.

Occurrence:—Locs. 2 and 12.

Genus *Amechilus* ROSS, 1951

ROSS (1951) compared *Amechilus* with *Hypothetica* having abnormal sutures and an unusually well developed marginal border. *Amechilus* looks to me more allied to *Leptopilus* RAYMOND. There are of course differences enough for their generic distinction. The glabella is cylindrical in *L. declivis* and long ovoid in *A. tuberculata* and intermediate in *A. palaora*. They are all short and narrow, the eyes being at the similar position. In *Amechilus* the anterior sutures are shifted inward, while the posterior ones are extended laterally. At the same time the convexity of the frontal limb is reduced. Such changes are frequently met with in the evolution of other trilobites. Therefore it is possible that *Leptopilus* is a collateral ancestor of *Amechilus*.

As noted elsewhere (1935), *Leptopilus* is similar to *Changshania* on one side and *Emmerichella* on the other. It looks more distant from *Liostracina* with which HUPÉ combined it in the same family (1953).

Amechilus tuberculatus KOBAYASHI, new species

Plate VI, figure 11.

Description:—Glabella short, half as long as the cranidium, long, ovate, strongly convex, distinctly elevated above the slightly inflated surroundings; a pair of weak lateral furrows extending obliquely from the lateral margin into the rear of the glabella; occipital furrow distinct and transversal; occipital ring thickened in the middle; dorsal furrow very strong; eyes of medium size, located at the mid-length of the cranidium, opposed at the anterior part of the glabella; no eye-ridge, but a shallow depression is seen on the cheek along the supposed position of the ridge; fixed cheek as wide as the glabella at the eye, but its posterior limb is far elongated laterally; frontal limb gently convex, as long as the glabella exclusive of the occipital ring; frontal limb depressed and narrow, but a little broadened toward the median point; facial sutures slightly divergent forward from the eyes; surface ornamented with minute tubercles.

Comparison:—In the major characteristics this agrees with *Amechilus palaora* ROSS which is represented by minute cranidia, about 2 mm. long or about a fourth as long as the holotype cranidium of this species. While this is a member of the *Kainella-Evansaspis* fauna, his species was procured from the E zone of the Garden City formation which is thought to be about the same age.

Its careful comparison with *A. palaora* shows that the glabella is more conical and probably more convex, the occipital ring narrows laterally, the eyes are located more anteriorly, the posterior limb of the fixed cheek is not pronouncedly dilated near the lateral end and the frontal rim narrower and distinctly depressed below the limb in his species.

Metabowmania latilimbata has a distinctly geniculate cranidium, still shorter, more ovate and convex glabella and the eyes at the more posterior position. The course of the anterior suture is not much different between the two species, but it is remarkable that the frontal rim is nearly straight and wire-like in *M. latilimbata*, but arcuate, flattened and mesially thickened in this species.

Occurrence:—Loc. 2.

Genus *Macroculites* KOBAYASHI, new genus

Diagnosis:—Cranidium with very long and narrow longiconic glabella, large semicircular thick eye-band and depressed narrow brim.

Type species:—*Macroculites enigmaticus* KOBAYASHI, new species.

Remark:—As further observations will be found in the description of the type species, this is a peculiar trilobite. *Leptopilus declivis* RAYMOND (1924) has a cylindrical glabella but not so long. Its eyes are neither so large nor so convex as in this genus. RAYMOND placed *Leptopilus* in the Stygidae, but as discussed elsewhere (1934), the genus looks to me likely a member of the Emmerichellidae.

In the cylindrical glabella this genus resembles *Teinistion* MONKE (1903), but in *Teinistion* the eyes are not so large and the frontal rim is distinctly convex, instead of concave in this genus.

In the large semicircular eye-band attached to the glabella this genus may be compared with the Kainellidae. *Pseudokainella* which is the most similar to this in that family has a cylindrical glabella

clearly outlined by dorsal furrows, but it is not so narrow and long as in this genus. A distinct rim usually present in the Kainellidae is another distinction from this genus.

In the aspect of eye-bands it resembles also the Anomocarinae POULSEN, especially *Haniwa* and *Haniwoides*. Like in this genus the preglabellar area is simply concave in *Haniwoides*, but it is much longer in that genus. The glabella is usually shorter, broader and less convex and eye-bands are more slender in the Anomocarinae.

In the development of the eye-bands it is comparable with the Redlichidae and Dolichometopinae. In the Dolichometopinae the bands are generally detached from the glabella at their posterior ends, except in *Acheilops*. The concave frontal brim of moderate size excludes this genus from the Dolichometopinae. The relation of this genus to the Redlichidae is presumed to be not close not only because of the long time difference between them but also because of the difference in the aspect of the preglabellar field.

Thus it is a question what family should this trilobite be put in. It is very tentative to put it in the Emmerichellidae. There is a pygidium contained in a small slab with the type cranidium. In size they are not improbable to belong to this form, but their combination needs much caution.

Distribution:—Lower Ordovician; western Canada.

Macroculites enigmaticus KOBAYASHI, new species.

Plate VI, figure 14; plate IX, figures 6a-b.

Description:—Cranidium with a long, cylindrical glabella about twice longer than broad, and a little expanded in the posterior part; two lateral furrows in the posterior half of the glabella cut into the glabella for a short distance; occipital furrow equally strong through its whole length; neck ring a little broadened in the middle; dorsal furrows conspicuously pronounced; eye-band large, semicircular, convex, broad, extending directly from the frontal lobe of the glabella and terminating at a short distance from the posterior lateral lobe; frontal brim short, depressed and concave; facial suture running forward and inward from a point on the eye-band at about a fourth of its length from the glabella; test smooth. The posterior limb of the fixed cheek is mostly unpreserved.

Occurrence:—Loc. 24.

Macroculites (?) sp.

Plate VI, figures 15a-b.

A pygidium found in association with *Macroculites enigmaticum* is semicircular in outline; axial lobe breviconic, but not strongly convex and only a little elevated above the horizontal side-lobes; these lobes, however, abruptly bent down near their periphery and merge into subvertical marginal border without any furrow; dorsal furrow strong; only an anterior ridge well marked by a furrow on the axial or pleural lobe.

The last thoracic segment is attached to the pygidium. It is similarly bent on the lateral sides as the pygidium and truncated at the ends. A furrow crosses the pleura diagonally; anterior ridge along the furrow forms the wall of a faceted area.

This resembles Ross' two undescribed pygidia (1950, pl. 30, figs. 13-16, and 20-21, 24), but in this pygidium the marginal border is more steeply inclined and the pleural furrow does not extend very far from the pleural platform.

Occurrence:—Loc. 24.

Family Olenidae BURMEISTER, 1843

The former tripartation of this family (WESTERGÅRD, 1922, KOBAYASHI, 1934) was lately emended by HARRINGTON and LEANZA (1952). The elimination of *Triarthrus* from the *Protopeltura* branch led them to the proposal of a new subfamily, Pelturinae. Because *Parabolinella* and *Triarthrus* are most probably direct derivatives from the *Olenus* stock, now I think it better to include the Triarthrinae, s. str. in the Oleninae.

As recently summarized by WILSON (1954), it is known at present that *Parabolinella* was widely distributed in North America in the late Upper Cambrian period. In the Lower Ordovician fauna of British Columbia the Olenidae are well represented by some genera and species. The distribution of the family in the two periods is known to be much wider than used to be considered,

Insofar as the cranidium is concerned, now I think that there is no objection against the placing of Upper Cambrian *Tostonia* or Lower Ordovician *Moxonia* in the Olenidae. The pygidium of *T. iole*

has distinct interpleural furrows, characteristic of the Olenidae. *Sphaerophthalmella* is a new genus here added to the Leptoplastinae.

Subfamily Oleninae KOBAYASHI, 1953

Genus *Parabolinella* BRÖGGER, 1882

Parabolinella bisulcata KOBAYASHI, new species

Plate VII, figures 18-19.

Description:—Glabella clearly outlined by narrow dorsal furrows, slightly longer than broad, subquadrate, a little narrowing forward, broadly rounded in front, gently convex, elevating toward its center and provided with two pairs of short oblique lateral furrows; occipital furrow transversal; median tubercle present on the occipital ring; eyes small, located anteriorly and connected with the frontal lobe of the glabella by a ridge which is nearly transversal; fixed cheeks inclined laterally, narrower than a half of the glabella, but its posterior limb is large and subtriangular; frontal limb large and crossed by fine subvertical striae; frontal rim a little arcuate, very narrow and raised; anterior facial sutures slightly divergent in front of the eyes.

Comparison:—Among the North American species of *Parabolinella* it is most closely allied to *P. lineatopunctata* KOBAYASHI (1936), but the lack of punctation in the marginal furrow is the distinction. The eyes are smaller and located more anteaally than in *P. evansi* KOBAYASHI. While only two pairs of lateral glabellar furrows are present in these three species, *P. incerta* RASETTI has three pairs. The frontal limb is narrow and the cranidium remarkably broadened posteriorly in the last species.

Occurrence:—Two cranidia from loc. 19, one of which appears to be compressed a little laterally.

Subfamily Leptoplastinae ANGELIN, 1854

Genus *Sphaerophthalmella* KOBAYASHI, new genus

Similar to *Sphaerophthalmus*, but the two pairs of lateral furrows are subequal in strength and length and disconnected on the axis of the glabella as in *Ctenopyge*; eyes located posteriorly, longer than that of other leptoplastids. Associated pygidium triangular as in *Sphaerophthalmus*.

Type species:—*Sphaerophthalmella inexpectans* KOBAYASHI, new species.

Remark:—It is certainly a remarkable fact that this genus is more related to the typical Atlantic trilobites than any of American ones. Further observations are found in the description of the monotypic species.

Distribution:—Lower Ordovician; western Canada.

Sphaerophthalmella inexpectans KOBAYASHI, new species

Plate VII, figures 10a-b and 11; plate IX, figures 12a-b.

Description:—Cranidium broad, trilobed by deep dorsal furrows into a glabella and two fixed cheeks of subequal breadth, each strongly swelling up; glabella a little larger and more elevated than the cheeks, slightly tapering forward, rounded in front, reaching the frontal furrow and laterally incised by two pairs of short oblique lateral furrows; occipital furrow distinct and slightly arcuate upward; occipital ring thickened toward the middle; eyes almost half as long as the fixed cheek, somewhat arcuate, subvertical and located far back; eye-ridge narrow, weak, directed toward the frontal lobe; occipital lobe transversal; frontal rim thick, convex, bent up mesially, separated from the glabella by a deep furrow; anterior facial sutures extending inward from the eyes; test smooth.

Associated pygidium is triangular in outline and provided with a narrow depressed rim; axial lobe conical, almost a third as broad as the pygidium, composed of about 5 rings and a terminal lobe, and elevated above the nearly flat and unfurrowed pleural lobes.

Comparison:—In the presence of the eye-ridge and weakening of the posterior furrow on the glabellar axis this is more allied to *Sphaerophthalmus major* LAKE (in WESTERGÅRD, 1922, pl. 13, fig. 16) than any of that genus.

Boeckia mobergi WIMAN inclusive of *Boeckia jarensis* STØRMER (1921) is so closely allied to this species that they are thought at first possibly congeneric. Compared to this, however, the glabella is more quadrate and longer, eyes a little smaller and the frontal groove and rim less developed in the Scandinavian species. The eyes are still smaller and located at the middle in the length of the cranidium in *Boeckia hirsuta* BRÖGGER which is the type of *Boeckia* BRÖGGER.

Occurrence:—Loc. 19.

Subfamily Pelturinae HARRINGTON and LEANZA, 1952.

Genus *Peltura* MILNE-EDWARDS, 1840*Peltura pacifica* KOBAYASHI, new species

Plate VII, figures 14-17.

Description:—Cranidium gently convex; glabella large, subquadrate, rounded in front, outlined by deep dorsal furrows, divided into a large frontal and two short lateral lobes by oblique furrows in two pairs which are disconnected from each other on the axis; occipital furrow subparallel to those lateral furrows, but runs across the glabella and more or less convex forward in the middle part; occipital ring bears a median tubercle; palpebral lobe small, located in the level through the middle of the frontal lobe and the interspace crossed by an eye-ridge; posterior limb of the fixed cheek as broad as a half of the glabella, inclined laterally; frontal rim separated from the glabella by a deep groove, and near the eyes there are a small depressed area; frontal groove punctated with fairly regular intervals; facial sutures anterior to the eyes very short and subparallel; their posterior branches running diagonally but with weak convexity toward the lateral sides.

Observation:—There are three cranidia beside a free cheek and a few fragmentary thoracic segments. The cheek is narrow and bears a genal spine. The test of this specimen is partly exfoliated. A pleura of the thoracic segment seems to be pointed at the lateral end but not prolonged into a spine. A furrow runs across the pleura diagonally.

Comparison:—According to BRÖGGER *Protopeltura* has genal spines but not *Peltura* s. str. WESTERGÅRD, however, included in it *Peltura cornigera* WESTERGÅRD which has genal spines. Generally speaking, the cranidium and fixed cheeks are narrower in *Peltura* than in *Protopeltura*.

In the large glabella which reaches the punctate frontal furrow, this species is quite similar to *Peltura punctata* CROSSFIELD and SKEAT from the British Tremadoc. The glabella in this species is, however, not expanded near the anterior margin as in that species, but forms rounded corners. The British species has no genal spine. Though narrow, there is a frontal limb in *Protopeltura granulosa* HARRINGTON and in *Peltura* (?) sp. from Argentina. Judging from

the anterior small eyes it is not a *Triarthrus*.

This is allied to *Westergardites pelturaeformis* TROEDSSON (1937), but the glabella is much broader, the eye lines take more anterior courses, and eyes are apparently more atrophied in that species.

Occurrence:—Loc. 9.

Peltura canadensis KOBAYASHI, new species

Plate VII, figure 20.

This is represented by a cranidium quite similar to the preceding, but the glabella is relatively long, its frontal lobe small in proportion to the two lateral lobes and the eye-ridge practically obsolete. As in *P. pacifica*, two pairs of lateral furrows are oblique to the axis, eyes small and located far anteriorly and the frontal furrow which separates a narrow rim and limb is pitted. The cranidium contained in the limestone is gently convex and its circum-glabellar furrow not so strong as in the preceding species.

Occurrence:—Loc. 20.

Genus *Jujuyaspis* KOBAYASHI, 1936

I proposed this generic name for *Jujuyaspis keideli* KOBAYASHI, (1936). It has no genal spine, but its facial suture cutting the lateral margin in front of a distinct genal angle, must be proparian. Subsequently its proparian nature was vindicated by *Jujuyaspis steinmanni* KOBAYASHI having the genal angle. Lately HARRINGTON and LEANZA (1952) proposed *Salteraspis* for *J. steinmanni* because their *keideli* is opisthoparian. It is then a question whether *keideli* is really proparian or opisthoparian.

The type specimens of *keideli* have a distinct postero-lateral angle on each fixed cheek. As clearly shown in fig. 7 in my paper (1936), the facial suture is transversal and cuts the margin of the cheek at some distance anterior to the angulation. Though somewhat obtuse, the angulation is also seen in *Jujuyaspis borealis* and the transversal posterior branch of the suture cuts the margin in front of the genal angle. Therefore the sutures of these trilobites are proparian, unless the angles are regarded intergenal, instead of genal. The angle in my *keideli*, however, is located at the point where the genal spine springs out in most other trilobites.

If HARRINGTON and LEANZA's *keideli* is compared with mine, there are some differences. Namely the glabella is more quadrate and the eyes are more widely apart from it in their form. Combined with the opisthoparian suture, or better to say the gonatoparian suture, these differences may be sufficient for specific distinction. Therefore I take the pleasure to denominate their gonatoparian *keideli* as *Jujuyaspis harringtoni* (nov.) in honour of Dr. Horacio J. HARRINGTON, a distinguished contributor to the knowledge on the Eo-Palaeozoic of South America.

Because *harringtoni* and *keideli* are so similar that the two have been considered an identical species by them, I do not intend to distinguish them in any higher rank than specific. I think it reasonable to consider in the case of *Jujuyaspis* that the facial suture loses its high value for classification. By this reason *Salteraspis* may be synonymized with *Jujuyaspis*.

Another proparian olenid was recently described from the upper Olenidian of Sweden. It is *Jujuyaspis* (?) *robusta* TJERNVICK, 1953, from the subzone with *Peltura scaraboeoides* and *Sphaerophthalmus* at Nerike. It has a genal spine. As the author reserved some question, it agrees better with *Acerocare* than *Jujuyaspis* in biocharacters other than the facial suture. It is, therefore, certainly an important fact that proparian forms appeared twice or more in different branches of the Pelturinae in the phylogerontic stage of the Olenidae.

Jujuyaspis borealis KOBAYASHI, new species

Plate VII, figures 12 and 13a-b.

Description:—Cranidium strongly convex, steeply slant on the lateral sides; glabella outlined by dorsal furrows, long, subconical, narrower than a third of the cranidium, rounded in front and unfurrowed except an occipital furrow; occipital ring thickened toward the middle; eyes small, longitudinally elongated, located far anteriorly and close to the glabella; ocular ridge absent; postero-lateral limb of the fixed cheek very large; its posterior margin distinctly bent antero-laterally at about the middle; occipital furrow deep and bent forward at the lateral end of the fixed cheek; preglabellar area narrow, gently convex, somewhat arched toward the axis; facial sutures parallel to each other in front of the eyes and then turn

inward; those posterior to the eyes transversal rather than diagonal; test smooth.

Comparison:—This resembles *Cyclognathus*, but differs in the posterior outline. Compared with *J. keideli* KOBAYASHI it is more convex, but the difference depends most probably upon preservation because the present cranidia are contained in gray limestone whereas the Argentina specimens are in black shales. The clear-cut distinctions between them are the more rounded anterior outline of the glabella and narrower space in its front in that species.

Occurrence:—Loc. 19.

Genus *Paenebeltella* ROSS, 1951

Paenebeltella convexa KOBAYASHI, new species

Plate VII, figures 21a–b; plate VIII, figure 12.

Description:—Cranidium trapezoidal, moderately convex; glabella elongately ovate, nearly as large as the fixed cheek and elevated above the cheek; occipital and dorsal furrows deep; occipital ring a little convex backward and thickened mesially; fixed cheek at the eye almost as wide as the glabella, gently convex and inclined distally; eyes small and located fairly anteriorly; ocular ridge generally absent; meso-occipital lobe thickened laterally and well defined by a deep furrow; frontal limb narrow, somewhat depressed; frontal rim uniform in thickness and straight in the dorsal view, but distinctly arched toward the axis in the frontal view; facial sutures convergent in the anterior and divergent in the posterior to the eyes, these branches being almost in the same line; test smooth.

Comparison:—The eye-ridges are, if seen by cross light, very faint and restricted to the vicinity of the eyes. On the exfoliate surface of a cranidium from loc. 7, the ridge is seen somewhat more clearly. It is transversal through the fixed cheek, but tends to turn backward to some extent near the eye. Lateral furrows are practically imperceptible even on the exfoliate surface of the glabella.

This species fits with *P. vultulata* ROSS so nicely that little doubt is left for their congenity. ROSS' two cranidia show the broadening of the cranidium as well as the glabella through growth. The present cranidium, notwithstanding the fact that it is larger than them, has a narrower glabella. The cranidium is more convex on a whole, fixed cheek more steeply slant, the eyes a little larger and

located more posteally and the frontal brim longer in this than in that species.

The lateral glabellar furrows are clearly impressed in British species of *Beltella*, at least in the casts, but become obscure in *B. ulrichi* (KAYSER). The distinct ocular ridge and divergent anterior branches of facial sutures are the chief distinctions of *Beltella* from *Paenebeltella*.

Occurrence:—Locs. 2 and 7.

Family Raphiophoridae ANGELIN, 1854

Genus *Ampyx* DALMAN, 1826.

Ampyx walcotti KOBAYASHI, new species.

Plate VIII, figures 1a-b, 2a-b, 3.

Description:—Cranidium nearly an equilateral triangle in outline; glabella swelling forward, most expanded at two-thirds the length from the neck, a little protruded beyond the frontal margin of the cheeks, highly elevated forward and upward, from the top of which an axial spine issues; a pair of weak furrows or shallow depressions impressed in the posterior part of the glabella; occipital furrow and ring moderately convex backward; cheeks gently inclined distally; posterior band on the cheek inclined toward the furrow in its front.

Pygidium broad, triangular; lateral margins disposed to form an angle of more than 120 degrees; axial lobe a little convex and slightly narrower than the flat pleural lobe which is in turn as long as the pygidium; no distinct furrow on these lobes except the first one; marginal border steeply inclined.

Test smooth.

Observation and comparison:—A free cheek possibly of this species is found near a cranidium in fig. 2a, but its outline cannot exactly be figured out. The axial spine is circular in cross section, insofar as can be judged from its broken point on this cranidium. A detached prismatic spine is found near the right genal angle of another cranidium in fig. 1a. The position, however, suggests its being more likely a genal rather than an axial spine.

The posterior furrow on the cheek is usually pitted near its lateral end. The dorsal furrow is also pitted in its anterior part, but not so distinct.

This species is similar to *Ampyx americanus* SAFFORD and VOGDES, but the cephalon and pygidium are broader in this than in that species.

Occurrence:—Loc. 13.

Ampyx walcotti var. *stenorachis* KOBAYASHI, new variety

Plate VIII, figures 4a-b, 5.

This form disagrees with the preceding in the broader outline of the cranidium and the slender glabella which is somewhat keeled along the axis.

The glabella is about half as wide as the cheek in this form whereas it corresponds roughly to two-thirds the breadth of the cheek in the preceding. The axial carina is especially distinct in the small cranidium in fig. 5. If better specimens will be obtained, this form may prove to be a distinct species.

Occurrence:—Loc. 13.

Ampyx, a sp. nov.

Plate VIII, figures 21-23.

Like *Ampyx nasutus* DALMAN the glabella is ovate and prominently elevated above the cheeks. On the exfoliated surface of the cranidium (a) it is seen that a pair of posterior depressions are incised so strongly that the outline of the glabella appears to be constricted in front of the neck ring. There are one or two more pairs of depressions but not so distinct. The occipital furrow on the cheek is pitted at four or more points as clearly seen on the left cheek of this cranidium. The axial spine is broken off in this, but preserved in another cranidium (b). It is rounded in cross section but somewhat angulated on the dorsal side.

The third cranidium (c) on the same slab has a glabella much shorter than those of the preceding cranidia. It is probable that this is shortened and the first one (a) elongated secondarily. The second one (b) which is intermediate may be about normal.

The pygidium half concealed beneath this cranidium (b) is triangular and lacks transverse furrows except the first one. The length and breadth of the pygidium are 5 mm. and 14 mm. respectively. The

length is equal to the breadth of the pleural lobe. In the broad outline it resembles the pygidium of *Ampyx semicostatus* BILLINGS which RAYMOND referred to *Rhaphiophorus*, but may be more allied to *Ampyx laeviusculus* BILLINGS in the obsoletion of segmentation.

Occurrence:—Loc. 7.

Ampyx, b sp. nov.

Plate VIII, figures 18–20.

In an incomplete cranidium from loc. 10 the glabella is subangulated along the axis, a pair of lateral furrows are strongly impressed in its posterior part and the frontal spine looks rounded in cross section. It is more similar to the preceding species than *Ampyx walcotti* or its variety.

The associated pygidium is nearly a right triangle in outline; axial lobe a fourth as wide as the pygidium; an anterior axial ring and pleural band depressed and marked off by furrows; marginal border subvertical. This pygidium is different from those of the preceding two species in the greater length.

Occurrence:—Loc. 7.

Family Shumardiidae LAKE, 1907

Genus *Shumardia* BILLINGS, 1865

Shumardia sp.

Plate VII, figure 9.

Description:—Cephalon semicircular, but slightly protruded and pointed at genal angles, strongly convex and steeply inclined near the anterior and lateral margins; glabella more elevated above the cheeks on the posterior than on the anterior side, narrower than a third of the cranidium in the rear part, dilating forward gradually and then abruptly expanded in the anterior in form of a mushroom; frontal lobe forms an obtuse angle at the top and rounded on the lateral sides; short furrow extending inward and forward from each side of the base of the lobe; no lateral furrow on the posterior lobe; occipital ring fairly thick and uniform in length; occipital furrow extends from the axial part into cheeks; dorsal furrows very strong on the sides of the posterior lobe, but become weak on the frontal

margin of the glabella; surface smooth.

Occurrence:—Loc. 2.

Genus *Lunacrania* KOBAYASHI, new genus

Shumardiidae with a long truncato-conical glabella and narrow marginal rim.

Type species:—*Lunacrania trisecta* KOBAYASHI, new species.

Remark:—Like *Idiomesus* RAYMOND, it has a narrow rim around the cephalon. This genus is, however, quite different from *Idiomesus* in the outline of the glabella, as can be easily understood by a comparison of *Lunacrania trisecta* with *Idiomesus tantillus* RAYMOND in RASETTI (1946).

Distribution:—Lower Ordovician; western Canada.

Lunacrania trisecta KOBAYASHI, new species

Plate VII, figure 8; plate IX, figure 10.

Description:—Cephalon strongly convex, semicircular, trisected by dorsal furrows which are pronounced backward; glabella long, truncato-conical, somewhat contracted at one-third from the front; two pairs of lateral furrows in the posterior part of the glabella short and pitted; occipital furrow well developed; cheeks a little protruded at the genal angles; rim narrow and depressed; test smooth.

Comparison:—In seeing the figure 16 of *Hardyia metion* (?) WALCOTT by KINDLE (1929), I am struck by its similarity to *Lunacrania trisecta*. WALCOTT's *Hardyia metion* has a broader cranidium and larger and more square glabella. The eyes are located more anteriorly than those of *Pagodia*. KINDLE's specimen may prove to be a member of *Lunacrania*, if it will be reexamined.

A cranidium which ROSS obtained from the zone B in the Garden City (1951, pl. 35, figs. 1-2) is similar to this and may be a member of the Shumardiidae.

Occurrence:—Loc. 24.

Order and Family uncertain

Genus *Rhamphopyge* KOBAYASHI, new genus

This name is proposed for the triangular convex pygidium pro-

vided with an unusually prominent nose-like axial lobe as typified by *Rhampophyge altipolum*. It is so isolated from other pygidia that there is least possibility of confusion.

Distribution:—Lower Ordovician; western Canada.

Rhampophyge altipolum KOBAYASHI, new species

Plate VI, figures 9a-b; plate IX, figures 8a-b.

A small pygidium subtriangular and 2mm. as long as broad; axial lobe prominently protuded above the steeply inclined side-lobes and somewhat swelling in the rear part; anterior two or three rings and ridges clearly separated from one another by transverse furrows; these ridges form serrations on the lateral margin; those furrows impressed in the middle part only near the axial furrows; marginal border narrow and depressed but more or less broadened and somewhat arched behind the axial lobe. Test smooth.

Occurrence:—Loc. 24.

Subclass Miomera Jaekel, 1909

Order Agnostida KOBAYASHI, 1935

Family Agnostidae MCKAY, 1849

Genus *Neoagnostus* KOBAYASHI, new genus

Diagnosis:—Cephalon with trilobed glabella and median preglabellar furrow; axis of pygidium trilobed, cylindrical and rounded off in the rear, leaving a narrow space in front of a posterior rim.

Type species:—*Neoagnostus aspidoides* KOBAYASHI, new species.

Remark:—The cephalon agrees with that of *Pseudagnostus* in essential aspects. The pygidium is, however, quite different from that of *Pseudagnostus* and closely allied to that of *Homagnostus*.

Distribution:—Lower Ordovician; western Canada.

Neoagnostus aspidoides KOBAYASHI, new species

Plate VII, figures 4-5; plate IX, figure 5.

Description:—Cephalon roundly quadrate, as long as broad and fairly convex; glabella about two-thirds as long as the cephalon and distinctly trilobed; middle lobe bisected by a short axial furrow; a

pair of lateral furrows widely diverging from this furrow at the ends; posterior lobe occupies a half length of the glabella; basal side-lobe triangular and relatively large; dorsal furrows quite pronounced and meet with each other at the front of the glabella whence a narrow axial furrow is extended forward; cheeks gently convex; flange fairly broad.

Pygidium strongly convex, subquadrate and surrounded by a relatively thick rim; axial lobe very prominent, outlined by a deep furrow, moderate in size and broadened in the anterior where a pair of triangular areas exist; median tubercle extends shortly forward and backward from the middle lobe; posterior lobe longer than the anterior or middle lobe, but shorter than a half of the axial lobe on the whole; side-lobe gently convex, only a little broader than the marginal rim; lateral rim narrows forward.

Test smooth.

Observation and comparison:—Four cephalons and a pygidium from loc. 24 are thought to belong most probably to an identical species, because there is no other agnostid at the locality and these carapaces agree in size, outline and convexity.

Some difference can be recognized among these cephalons as to the proportional size of the three lobes of the glabella. A median tubercle appears to be usually present at the anterior end of the posterior lobe. The tubercle is, however, not so distinct as usual in *Pseudagnostus*, but so small and improminent that it can be overlooked.

The pygidium is similar to *Geragnostus subobesus* (KOBAYASHI) from the *Symphysurina* limestone in the Yukon-Alaska boundary region (1936), but its outline is longer and the axial lobe distinctly expanded laterally near the anterior margin.

Occurrence:—Loc. 24.

Genus *Hyperagnostus* KOBAYASHI, new genus

Diagnosis:—Cephalon with trilobed glabella but without median preglabellar furrow; axis of pygidium cylindrical, trilobed and moderate in length.

Type species:—*Hyperagnostus binodosus* KOBAYASHI, new species.

Remark:—It is quite probable that this genus was introduced from *Neagnostus* by obsoletion of the median furrow because the two genera agree with each other in many other aspects and because

this is younger than that genus. A prominent node at the genal angle seen in the type species is a very distinctive feature not seen in *Neoagnostus aspidoides*.

Distribution:—Lower Ordovician; western Canada.

Hyperagnostus binodosus KOBAYASHI, new species

Plate VII, figures 2-3; plate IX, figure 4.

Description:—Cephalon strongly convex, steeply inclined near a narrow flange; glabella prominently elevated above the cheeks and trilobed; anterior lobe fairly large; two pairs of lateral furrows which join at a point outline two triangular depressed middle lobes; median tubercle lying just behind the intersection, fairly large; posterior glabellar lobe and basal side-lobes well developed; posterior flange narrow; and circular tubercles exist beyond its lateral end.

Pygidium also strongly convex, as long as broad and parallel sided; posterior margin broadly rounded; axial lobe cylindrical, half as broad as the pygidium, rounded at a short distance inside the posterior rim, scarcely elevated above the general convexity of the pygidium, outlined by narrow dorsal furrows and divided into two major parts by a shallow transverse furrow, the posterior one being longer than the other; anterior part provided with a long median ridge and its lateral sides each bisected by a transverse furrow; pleural part as wide as the post-axial part; flange well developed; no posterior spine on the flange.

Occurrence:—Loc. 2.

Genus *Geragnostus* HOWELL, 1935

Geragnostus aff. *mundus* (RAYMOND)

Plate VII, figure 1, plate VIII, figure 17. •

1925. aff. *Peronopsis mudus* Raymond, *Bull. Mus. Comp. Zool. at Harvard Coll.* Vol. 67, p. 14 pl. 1, fig. 7.

Cephalon fairly convex, roundly subquadrate, a little narrowing forward; glabella clearly outlined by deep dorsal furrows, about a third as broad as the cephalon, strongly convex, elevated high up above the cheeks, subconical, rounded in front and distinctly bilobed by a strong transverse furrow; posterior lobe large, strongly vaulted posteriorly; basal side lobes small, triangular and depressed; cheeks

gently convex and steeply slant distally; marginal rim very narrow.

The preglabellar area is not well preserved, but it can be definitely said that there is no axial furrow. The posterior lobe of the glabella is partly broken, but a median tubercle is seen in front of this broken part.

The associated pygidium is quadrate; its narrow rim protruded into a tiny spine at the postero-lateral angle; axial lobe as long as three-fourths the pygidium, strongly convex, elevated above the moderately convex side-lobes and trilobed by transverse furrows; second lobe carrying a median tubercle.

Peronopsis munda RAYMOND from the Lower Ordovician in the Sinclair canyon near Lake Windermere, southeast of Golden, British Columbia, is probably a *Geragnostus* similar to this, but having a more cylindrical glabella.

Occurrence:—Loc. 23.

Genus *Trinodus* MCCOY, 1846

Trinodus priscus KOBAYASHI, new species

Plate VII, figure 6.

Description:—Pygidium subquadrate, nearly as long as broad, distinctly expanded postally, moderately convex and surrounded by a narrow rim; lateral rim straight and produced behind into a short spine; posterior margin between the spines gently arcuate. Axial lobe half as long and as broad as the pygidium, but narrowing backward and trisected by two pairs of lateral furrows, the anterior ones of which are, however, not so strong as the posterior ones; median tubercle long and prominent on the middle lobe; posterior lobe bisected by a median depression.

Comparison:—At a glance this pygidium reminds one of *Pseudagnostus*, but there is no posterior pseudolobe and the short axial lobe trilobed, instead of bilobed as in *Pseudagnostus*. The straight lateral margins and posterior expansion of the pygidium are distinctive characteristics among the species of *Trinodus*.

Occurrence:—Loc. 15.

Trinodus tardiformis KOBAYASHI, new species

Plate VII, figures 7a-b.

Description:—Pygidium broader than long, subquadrate, but broadly arcuate along the posterior margin, most prominent at the

median tubercle; axial lobe occupies a third of the anterior margin, subovate, half as long as the pygidium, clearly outlined by a narrow but deep furrow, highly elevated above the side lobes and provided with two pairs of lateral furrows the anterior ones of which being stronger and turning forward so as to outline the antero-lateral area; median tubercle prominent, located a little posterior to the frontal margin; side lobes equally wide on the lateral and posterior sides of the axial lobe, inclined distally with strong convexity; marginal rim narrow and convex, separated from the side lobes by a deep furrow; test smooth.

Comparison:—Most of *Trinodus* have longer and more rounded or ovate pygidia. In the broad quadrate outline this is closely allied to *Trinodus tardus* (HAWLE and CORDA). This pygidium is, however, more convex and its marginal furrow and rim are evidently narrower, if compared to that species (WHITTINGTON, 1952, pl. 68, figs. 4-6).

Occurrence:—Loc. 10.

Postscript

1. *Housiella* was proposed by KOBAYASHI for *Ceratopyge canadensis* WALCOTT and combined with *Housia* WALCOTT in the Housiinae KOBAYASHI, new subfamily, which is in turn tentatively referred to the Ceratopygidae RAYMOND.
KOBAYASHI, T. and ICHIKAWA, T. (1955), Discovery of *Proceratopyge* in the *Chuangia* zone in Manchuria with a Note on the Ceratopygidae. Miscellaneous Notes on the Cambro-Ordovician Geology and Palaeontology, No. XXV. *Trans. Proc. Palaeont. Soc., Japan, N.S.*, No. 19.
2. TJERNVIK instituted *Nericiaspis*, nov. on the basis of *Jujuyaspis* (?) *robusta* TJERNVIK, 1935, and placed it in the subfamily Pelturinae HARRINGTON and LEANZA, 1952, in the family Olenidae BURMEISTER.
TJERNVIK, T. (1955), *Nericiaspis*, a new genus of Proparian Olenid. *Geol. Fören. i. Stockholm, Förhandl. Bd. 77*.

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Plate I

Explanation of Plate I

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Explanation of Plate II

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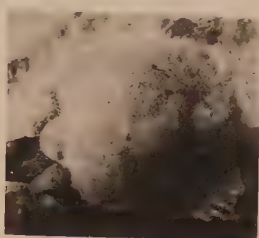
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Explanation of Plate III

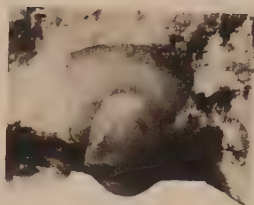
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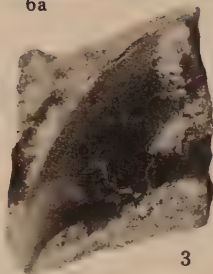
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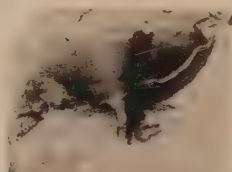
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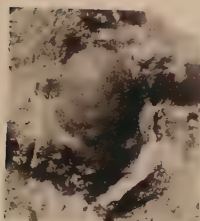
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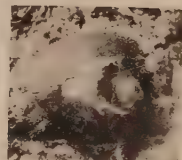
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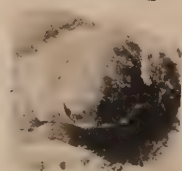
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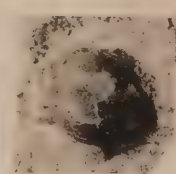
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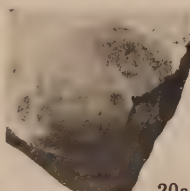
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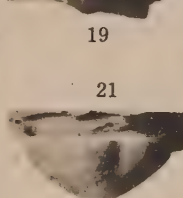
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Plate IV

Explanation of Plate IV

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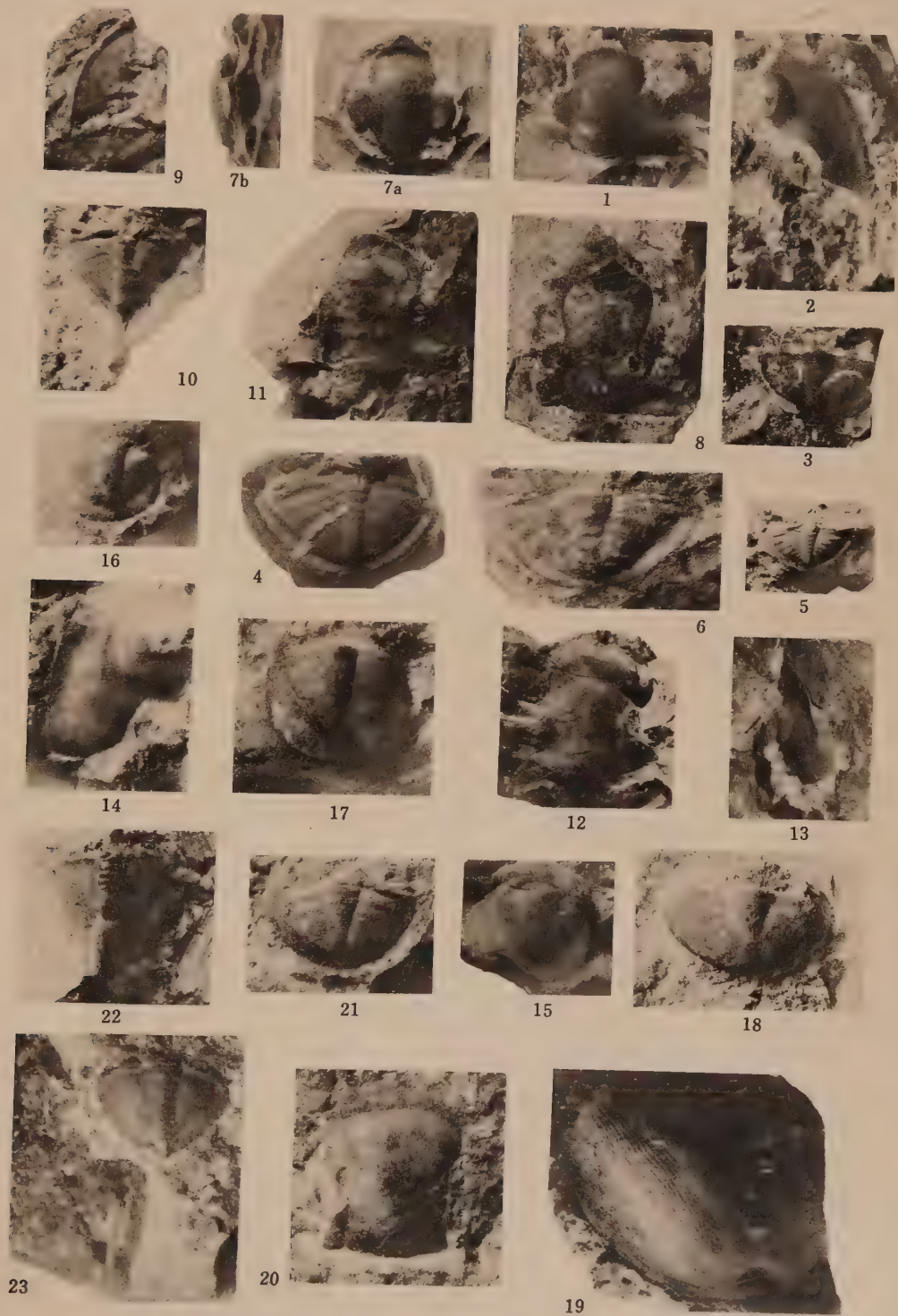


Plate VI

Explanation of Plate VI

Ordovician Trilobites from the McKay group in British Columbia.

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Plate VII

Explanation of Plate VII

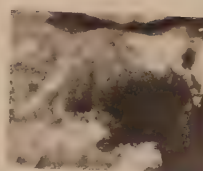
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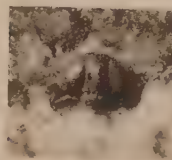
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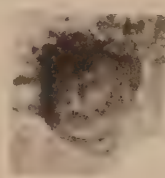
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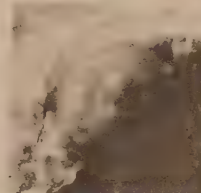
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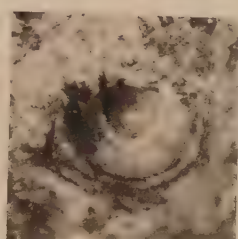
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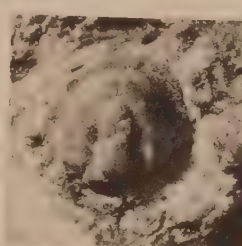
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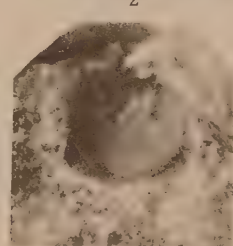
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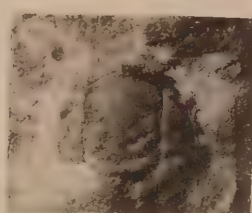
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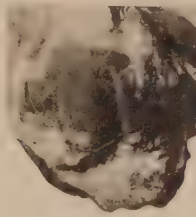
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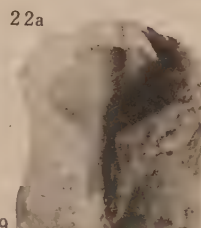
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21a



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22a

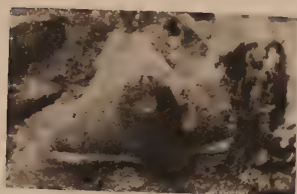


22b

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Explanation of Plate VIII

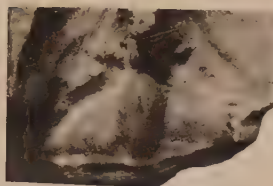
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1a



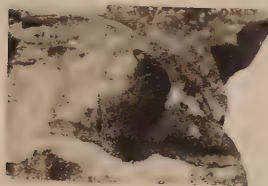
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4b



2a



2b



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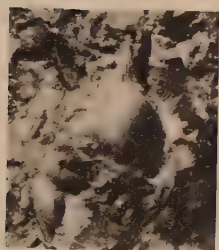
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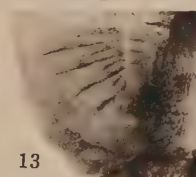
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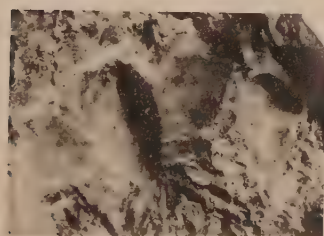
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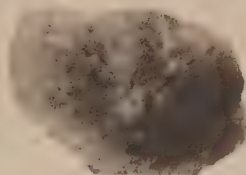
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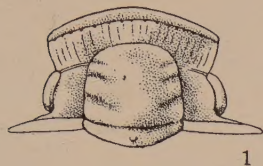


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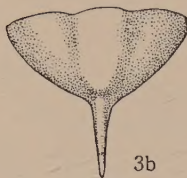
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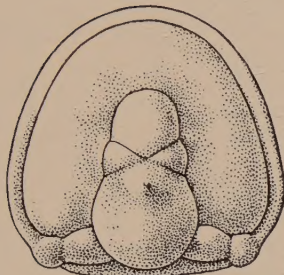
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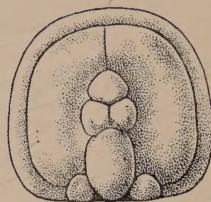
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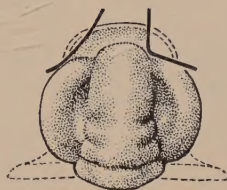
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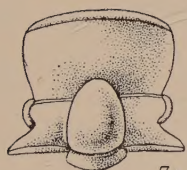
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7a



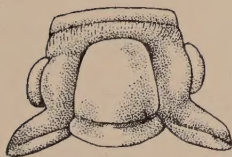
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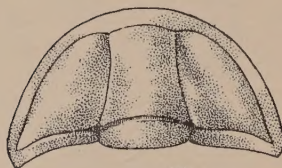
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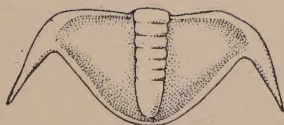
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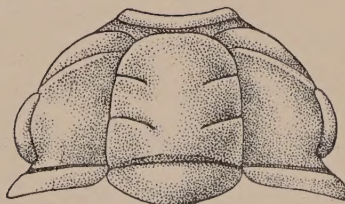
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